ERRORS IN SKILLED COMPLEX ACTIONS:

PSYCHOLOGICAL, BIOMECHANICAL, AND NEUROPHYSIOLOGICAL ASSESSMENTS OF THE YIPS IN GOLF PUTTING

PHILIPP B. PHILIPPEN

Diese Dissertation ist gedruckt auf alterungsbeständigem Papier °°ISO 9706

Ehrenwörtliche Erklärung zur Dissertation

Philipp Bennet Philippen
Geboren am 08.04.1982 in Berlin

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mit dem Titel: „Errors in Skilled Complex Actions "**

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DISSERTATION

Dissertation zur Erreichung des Doktorgrades der Philosophie (Doktor philosophiae; Dr. phil.) an der Fakultät für Psychologie und Sportwissenschaften an der Universität Bielefeld.

ZUGEHÖRIGKEIT

Die in dieser Dissertation beschriebenen Arbeiten fanden von 2009 bis 2010 in der Abteilung Leistungspsychologie des Psychologischen Instituts der Deutschen Sporthochschule Köln statt. Von 2010 bis 2012 wurden die Arbeiten in der Arbeitsgruppe für Neurokognition und Bewegung – Biomechanik, der Fakultät für Psychologie und Sportwissenschaften sowie der von der Deutschen Forschungsgemeinschaft (EXC. 277 DFG) geförderten Graduiertenschule des Center of Excellence „CIT“ (CITEC) der Universität Bielefeld fortgeführt.

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FÜR MEINE ELTERN

DANKSAGUNG

Ich möchte an dieser Stelle meine Dankbarkeit für die Unterstützung ausdrücken, ohne welche diese Dissertation niemals entstanden wäre.

Prof. Dr. Thomas Schack danke ich für die Möglichkeit, meine Arbeiten in einem inspirierenden Umfeld und in einer finanziell abgesicherten Situation durchführen zu können. Außerdem danke ich Dir, lieber Thomas, für die inhaltliche Betreuung, die - nicht nur - den Rahmen dieser Dissertation entscheidend geprägt hat. Ich danke Dir für Deine Unterstützung und Dein Verständnis für persönliche Entscheidungen und Lebensumstände. Die vielen unterhaltsamen Abende wollen wir an dieser Stelle weder verschweigen noch vergessen, aber damit sei auch genug gesagt.

Desweiteren möchte ich mich bei Dr. Babett Lobinger und Prof. Dr. Dr. Markus Raab bedanken, ohne die ich nie zu dem Thema dieser Dissertation gekommen wäre. Ich danke Euch beiden für Euer Vertrauen in meine Kompetenzen sowie das Angebot und die Möglichkeit, meine Promotion unter Eurer Obhut beginnen zu können. Eure Unterstützung hatte maßgeblichen Einfluss auf den Inhalt und die Form dieser Dissertation und ich hoffe, dass die vorliegende Arbeit der weiteren Yips-Forschung an der Deutschen Sporthochschule dienlich ist.

Bei Dr. William Land möchte ich mich für seine Betreuung und kritische Perspektive auf meine Arbeiten bedanken. In Dir, Billy, habe ich einen wahren Experten für Golf und Aufmerksamkeit gefunden. Und nicht zu vergessen ist Arthur Legler: Ohne Dich wäre die letzte Studie in dieser Form nicht möglich gewesen – Du bist der beste Hacker, den ich kenne.

Patricia Land und Borghild Figge gebührt mein Dank für das endgültige Korrekturlesen dieser Arbeit. Besonders hervorheben möchte ich auch noch die Unterstützung und Begleitung all meiner Kolleginnen und Kollegen in Bielefeld und in Köln. Danke Euch allen für eine prägende Zeit.

Auch wenn Ihr vermutlich nie so genau verstanden habt, was genau ich mache und warum das so lange dauert, habt Ihr mich immer unterstützt und ermutigt, weiterzumachen. Ohne Eure bedingungslose Unterstützung wäre ich wohl auf halber Strecke liegen geblieben. Vielen Dank für alles an meine Familie!

Gesondert und insbesondere gebührt mein Dank meiner Liebe, Gabriella. Deine Geduld habe ich vielfach auf die Probe gestellt und Du hast die Prüfung mit Bravour gemeistert. Ich danke Dir für Deinen Verzicht und die Kompromisse, die Du für uns und für mich gemacht hast. Ich liebe Dich.

Abschließend bedanke ich mich für die Finanzierung der Arbeiten bei der Hochschulinternen Forschungsförderung der Deutschen Sporthochschule Köln sowie bei der von der Deutschen Forschungsgemeinschaft (EXC. 277 DFG) geförderten Graduiertenschule des Center of Excellence „CIT“ (CITEC) der Universität Bielefeld

DANKE!

Philipp

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The empirical work presented in this dissertation is based on following articles:

Philippen, P. B., & Lobinger, B. H. (2012). Understanding yips in golf: Thoughts, feelings, and focus of attention in yips-affected golfers. *The Sport Psychologist, 26*, 325-340.

Philippen, P. B., Klämpfl, M. K., & Lobinger, B. H. (under review). Prevalence of the yips in golf across the entire skill range. *Human Movement Science*.

Philippen, P. B., Legler, A., Land. W., Schuetz, C., & Schack, T. (under review). Diagnosing and measuring the yips in golf putting: A kinematic description of the involuntary component that is the yips. *Sport, Exercise and Performance Psychology.*

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SUMMARY

History has shown that we often learn what is right from what is wrong. To understand more about human motor control, this dissertation investigates a systematic error that occurs in complex human actions, referred to as 'the yips'. The yips has been defined as an involuntary muscle contraction that results in a jerk, tremor, or freezing of a planned movement. In golf, the yips occur most often during the putting stroke. The etiology of the yips is still unclear. It has been postulated that the yips might be a form of task-specific focal dystonia (TSFD), which is a movement disorder affecting highly trained fine-coordinated movements such as playing an instrument or writing. It is argued that typical TSFD symptoms such as abnormal postures or tremors are related to neurophysiological abnormalities. Alternatively, it has been suggested that the yips might be a severe form of choking under pressure, which is a significant drop in one’s performance in situations of perceived high pressure. It is argued that choking might be caused by the adoption of a dysfunctional focus of attention during the execution of the affected movement. Currently, it is argued that the reasons for the yips reside on a continuum, with mechanisms of focal dystonia on one pole and mechanisms of choking under pressure on the other pole.

The yips can be devastating for one’s performance and sometimes even one's professional career. It seems that the yips are fairly widespread across highly skilled golfers; Yet, despite its prevalence and its impact on performance, there is a paucity of reliable interventions to cope with the yips in golf putting. One reason for this lack of interventions is certainly the unclear etiology of the yips. The purpose of this present dissertation is to enhance the understanding of the etiology of the yips in golf putting. This is not only crucial to eventually be able to advise yips-affected golfers on how to cope with the yips, but also will promote our general understanding of motor control, and especially its disturbances.

The research in this dissertation focuses on psychological, behavioral, and physiological aspects of the yips in golf putting. Furthermore, it extends the suggestions of potential underlying reasons of the yips in golf putting. Last but not least, the dissertation provides the first scientifically developed yips-relevant diagnostic criteria and a procedure to objectively assess the yips in golf putting.

More specifically, in chapter 2 the psychological components of the yips in golf are addressed. Although it has been suggested that the yips might be a form of

choking, to date no investigations of the thoughts and focus of attention of yips-affected golfers have been published. Given the importance of attention and arousal in explaining choking, we conducted an interview study to investigate the thoughts, feelings, and focus of attention in yips-affected golfers. Based on the aforementioned continuum model, we expect the yips-affected golfers to mainly focus on worries or the movement execution when having to take a putt. From the interviews, it becomes apparent that yips-affected golfers have a negative (i.e., dysfunctional) cognitive and emotional association with the task of putting (i.e., a yips-affected stroke). The results show that the golfers were predominantly occupied with negative thoughts such as perceived loss of control, loss of confidence in their putting skills, and worries about mistakes due to the yips. In addition, the feelings associated with the yips were exclusively negative, including disappointment, frustration, anger, and especially anxiety about having to take a putt. In addition to exhibiting this negative cognitive and emotional pattern, 11 of the 17 participants reported a focus on technical aspects or a focus on the yips and its negative performance outcomes. The results support the previous postulation that the yips symptoms of some golfers are related to mechanisms similar to the ones underling choking under pressure. The present study provides a possible starting point for the development and evaluation of interventions for the yips. The present categorization promotes a better understanding of how golfers experience the yips and which processes might be involved in the yips and its long-term nature. This provides practitioners with valuable information to develop effective treatment.

In chapter 3, the suggestion that predominately highly skilled golfers are affected by the yips is addressed. This suggestion is one of the main reasons for the postulation that the yips might be a form of TSFD, because TSFDs usually affect highly trained skills. However, as has been pointed out above, it is not known whether relatively untrained golfers also experience the yips, because to date only professional and highly competitive golfers have been investigated. Therefore, we designed an online questionnaire to assess the prevalence of yips in golf across the entire skill range. Based on the suggestion that the yips are a form of TSFD, we expect that only highly experienced golfers are affected by the yips. The results revealed that across the entire skill range, 22.4% of golfers surveyed reported being currently affected by the yips. Furthermore, although the results show that novice golfers also report being affected by the yips, the prevalence of the yips is higher across more highly skilled golfers.

In addition to the prevalence and characteristics of the yips, we also assessed which other movements are affected by yips-like symptoms. The results motivated a subsequent online inquiry, investigating the sports history of a subsample of participants from the first questionnaire. The results show that more yips-affected than unaffected golfers had played a sport that requires the interception of a ball with an object that is controlled with the hands. Since the prevalence of yips in golf is higher than the prevalence of other TSFDs, we suggest that there might be multiple causes for the same yips symptoms that have not yet been explored. Based on our results, we propose a possible relationship between the yips in golf and a certain sports history.

In chapter 4, we address the behavioral and physiological components of the yips in golf putting. Specifically, we address the paucity of an objective diagnosis of the yips. We present a biomechanical analysis of the yips in golf putting to identify its physical manifestation. Using kinematic analyses, we establish the first objective diagnostic criteria to distinguish yips-affected putts from unaffected putts. The results show that the yips were provoked 100% reliably when putting the ball with the dominant hand only. Also, the yips largely disappeared when there was no ball. Moreover, kinematic analyses show that a higher maximal rotation velocity and a larger number of directional changes in the affected wrist's rotation clearly distinguished the yips-affected putts from unaffected putts. The EMG results revealed no significant differences between yips-affected and unaffected putts. Overall, the results show that putting the ball with the dominant hand only reliably provokes yips that can be measured by the wrist's rate of rotation and the number of the rotation's directional changes. This procedure allows for an accurate diagnosis of the yips in putting as well as a way of reliably provoking the yips in laboratory settings. This is especially valuable for future studies on the yips which aim to assess the effectiveness of interventions or the effect of experimental manipulations. We conclude this chapter with a revised definition of the yips in golf putting and recommendations for how to diagnose the yips in future studies, as well as on the golf course.

In the concluding chapter, we discuss the current findings in the framework of a more general model of motor control and propose an alternative explanation for the causes of the yips in golf putting.

1. CHAPTER – GENERAL INTRODUCTION

1.1. General Introduction

Moving is the only way to interact and affect the world around us. Whether we type, write, talk, point or make a grimace, we always produce movements by contracting muscles. Realizing that moving is our only – well except for producing odors – tool for interacting with the world, makes it even more surprising how little we know about the control of our movements. Investigating the acquisition and control of movements is a complex interdisciplinary endeavor and most often requires a controlled environment. The environment of sport is an optimal setting to investigate motor learning and motor control, because it provides an environment governed by clear rules. Moreover, it requires learning and performing of motoric skills often under pressure and allows its evaluation in clear terms of success and failure. Therefore, this present dissertation is residing in the area of sport psychology and motor control.

1.2. The Cognitive Architecture of Complex Movements

The fundamental goal of every theory of motor control is to understand and explain how we can control and adapt complex movements in our environment. Whether we adopt a perspective of central control mechanisms (Schmidt, 1975) or environmental control mechanisms (Kelso, 1995), it is essential for every theory of motor control to solve the degree of freedom problem (Bernstein, 1967). The degree of freedom problem "occurs in the designing of a complex system that must produce a specific result; the design problem involves determining how to constrain the system's many degrees of freedom so that it can produce the specific results" (Magill, 2007, p. 85). In other words, how can we control and coordinate all the muscles and joints to produce a specific movement? A comprehensive model that provides a theoretical framework for the control of complex movements is the cognitive action architecture approach (CAA-A; Schack, 2004), which is based on the ideas of Bernstein.

The CAA-A builds on the idea of Bernstein that superfluous degrees of freedom need to be transformed into goal-directed movement effects. According to Schack (2004), this transformation requires specific building blocks, which need to be functionally interconnected. These building blocks are organized in four hierarchical levels (see Table 1.1.). The top level (level IV) of the model represents the mental control of movements, and has a regulatory function. That is, on this level we decide what kind of action to perform. One of the most important functions of this level is to transfer our intentions into action goals, for example, by anticipating the effect or the final posture of the movement (see Hommel, Muesseler, Aschersleben, & Prinz, 2001; Rosenbaum & Jorgensen, 1992). On the next level (level III), mental representations of basic concepts of a movement serve as a cognitive benchmark for the action goals initiated by the upper level of mental control. The representational units on this level are called Basic Action Concepts (BACs). BACs have already been identified for various movements, for example, the tennis serve (Schack & Mechsner, 2006) or a throwing technique in judo (Weigelt, Ahlmeyer, Lex, & Schack, 2011). BACs have both functional and sensory features (Schack, 2004). The functional features link the BACs to the action goals of the upper level, whereas the sensory features connect the BACs to the lower level of sensorimotor representation (level II). The level of sensorimotor representation contains units which represent perceptual effects, afferent feedback, and effectors. Schack (2004) assumes that this level is where the sensory modality-specific information is stored. The units on this level are the sensory effects of the movement within the volitionally-initiated action on level IV. The lowest level (level I), the level of sensorimotor control, is directly related to the environment. Functions and controls on this level are perceptually induced and function under the guidance of the anticipated sensory information represented in the upper levels. Representation and control of the sensorimotor system are interdependent, and change depending on the stage of learning and the task (i.e., action) at hand.

The CAA-A presents a comprehensive account for the way complex movements are controlled, reaching from the intentional initiation of the action to the lowest level of sensorimotor control of any movement. Moreover, the model is supported by neurological findings illustrating a hierarchical structure for action in the brain (Grafton & Hamilton, 2007). It serves as a sound theoretical framework for the investigation of motor control. Its strength lies amongst others in the definition and organization of the different levels of motor control. Therefore, the model allows for assigning research on motor control to specific levels. The motor control research that is at the core of this dissertation will be embedded in the model at the end, and will provide a framework for future studies.

Table 1.1. – Levels of Action Organization According to Schack (2004)

Code	Level	Main function	Subfunction	Means
IV	Mental control	Regulation	Volitional initiation, control strategies	Symbols; strategies
III	Mental representation	Representation	Effect-oriented adjustment	Basic action concepts
II	Sensorimotor representation	Representation	Spatial-temporal adjustment	Perceptual effect representations
I	Sensorimotor control	Regulation	Automatization	Functional systems; basic reflexes

1.3. THE IMPORTANCE OF UNDERSTANDING HUMAN ERRORS

Many questions about the control of movements are still unanswered. For example, how come humans sometimes fail to control their movements, or fail to reach the intended outcome? Only a few realize the importance of mistakes in the way Michael Jordan did when he said “I've missed more than 9000 shots in my career. I've lost almost 300 games. 26 times, I've been trusted to take the game winning shot and missed. I've failed over and over and over again in my life. And that is why I succeed.” The reason people fail to realize the importance of mistakes is probably that failure can often come at a high cost in many areas of expertise. Particularly in sports, the cost of failure can become evident instantly. For example, the split seconds that it takes to miss a penalty in soccer or a putt in golf can not only cost you the victory or even the championship that you have worked toward for many years, it can also cost you millions in prize money. Such failures are not only financially expensive, but can also be emotionally burdensome. Consequently, finding ways too avoid or understand failures have been the interest of many (e.g., Beilock & Gray, 2007; Hill, Hanton, Matthews, & Fleming, 2010; Masters & Maxwell, 2008; Reason, 1990).

Preventing failures or errors is not only financially and emotionally profitable, it often also reveals insights into the underlying mechanisms of errorless processes. We often learn what is right from looking at what is wrong, because often “knowledge and error flow from the same mental sources, only success can tell the one from the other” (Mach, 1905; cf. Reason, 1990, p. 1). For instance, patient H.M. suffered from the bilateral removal of the hippocampus and consequently could not learn new words or remember people he had met after the surgery. Yet, he was able to learn new movements such as the mirror tracking task, and therefore demonstrated that declarative and procedural knowledge are stored in different locations in the brain. Similarly, patient D.F., who suffered from a monoxide intoxication, was consequently unable to name or describe sizes, shapes, or locations of familiar objects. She was, however, able to shape her hand appropriately and manipulate the objects in an instructed way within the environment. This finding strongly inspired the widely accepted notion of two visual pathways, one for perception and one for action (Milner & Goodale, 2008). These examples illustrate the potential of investigating errors for the more general understanding of processes. The idea that in order to fully understand control processes, we also need to understand the varieties of human fallibility is in line with great scholars such as James Reason (1990), who dedicated his work to the investigation of human error. Thus, with the goal of promoting the understanding of complex motor control, the investigation of a failure to control a complex movement is at the core of this present dissertation. Specifically, the failure investigated in the present dissertation is the yips in golf putting.

1.4. The Term Yips and its Historical Development

The term yips is said to have been coined by the famous professional golfer Tommy Armour. He won 25 PGA (professional golf association) tournaments between 1920 and 1938 before he had to end his career due to severe problems while putting the golf ball. He called his putting problems "yips," because to him the term described best how the problem felt (http://en.wikipedia.org/wiki/Yips). Other prominent golfers who have been affected by the yips include Ben Hogan, Sam Snead, and Bernhard Langer who is arguably one of Germany's most successful golfers (Pelz & Frank, 2000). Bernhard Langer once described the yips as "a jerky, uncontrolled putting stroke that sends scores soaring" (Langer, n.d.). This jerky, uncontrolled putting stroke even caused him to need 5 putts to hole the ball from about 1-meter at the 17th hole on the final day of the British Open (Der Spiegel, 1988). As he said himself, "All of my career I have struggled to control the yips. […] Those were extremely difficult times. I often thought about quitting." (Langer, n.d.). The term yips is currently used as a colloquial term, referring not only to the disruption of the putting stroke, but also to problems in other strokes such as the chip or the drive (see http://en.wikipedia.org/wiki/Yips). Even in other sports, such as Cricket, Baseball, or

Darts, the term yips is used to describe uncontrollable problems with the movement execution (Bawden & Maynard, 2001).

This colloquial use of the term yips, however, does not simplify matters. It is not clear if all the problems generally described as yips are caused by the same underlying mechanisms or even manifest in the same physical symptoms. For instance, reports about the yips in cricket describe the bowlers' inability to release the ball rather than a jerky disruption of the putting stroke (Bawden & Maynard, 2001). These are not only two fundamentally different movements, but also completely different physical manifestations of a problem. The broad application of the term across sports and motions complicates the investigation of the yips, because it produces knowledge about phenomena that are treated as equal, but are not necessarily the same. To understand what the underlying mechanisms of the yips are and how it can be treated, it is necessary to establish an agreement of what the term yips actually refers to. Therefore, the focus of the experimental investigations in this dissertation is restricted to the original phenomenon of yips in golf putting. The focus on golf putting as a yips-affected task suggests itself merely by the number of published studies about the yips. The scientific literature on yips is generally very limited, totaling to the best of our knowledge only nine peer-reviewed journal articles, of which eight are about the yips in golf putting. Thus, investigating yips in golf putting allows us to build upon an existing knowledge base. The next paragraphs will summarize what is known about the yips in golf putting.

1.5. THE YIPS IN GOLF PUTTING

The previous section illustrated how devastating the yips in golf putting can become for someone's performance and even professional career. Despite these severe consequences, the yips have received rather limited attention in the scientific literature. Currently, it is neither well understood what causes the yips nor what kinds of treatments reliably cure the yips. The following paragraphs describe the scientific state of the art of the yips in golf putting. It will begin by providing a definition of the yips, followed by a kinematic description of its physical manifestations, and a summary of its characteristics such as prevalence, situational occurrence, and physiological characteristics. Finally, the current postulations about the underlying causes will be elaborated.

1.5.1. THE DEFINITION OF THE YIPS IN GOLF

The first published study investigating the yips in golf putting dates back to 1989 (McDaniel, Cummings, & Shain, 1989). McDaniel and colleagues described the yips as “a motor phenomenon that affects golfers and consists of involuntary movements occurring in the course of the execution of focused, finely controlled, skilled motor behavior” (p. 192). More recently, the yips has been defined as “a motor phenomenon of involuntary movements” manifesting in “a jerk, tremor or freezing in the distal upper extremity that interrupts the putting stroke” (Smith et al., 2003, p. 13-14). Both definitions are the same at their core, emphasizing the involuntary movements that occur during a planned movement. The more recent definition adds specifications of the physical manifestations, which is an important addition in order to narrow down the rather broad definition of the yips. However, it is not clear if the specification of the physical manifestation is accurate, since it is solely based on participants’ self-description. To date, it remains unclear how this involuntary movement manifests, and if it does so in the same way across all yips-affected golfers. The essential aspect of the definition of the yips is the disruption of a planned (i.e., intentional) movement by involuntary movements. How these involuntary movements might manifest will be addressed next.

1.5.2. THE PHYSICAL MANIFESTATION OF THE YIPS IN GOLF

The first scientific description of the physical manifestation of the yips in golf was based on the questionnaire results of McDaniel et al. (1989). Based on the reports of 93 yips-affected professional and highly competitive golfers, the involuntary movements were described as “jerks (49%), jerks and tremors (9%), tremors (8%), jerks and spasms (7%), and spasms (4%). A combination or ‘other’ description was given in 23%” (p. 193). Only recently, due to advances in technology, more detailed kinematic descriptions of the yips in golf putting are available (Adler et al., 2011; Marquardt, 2009). In one study, the golf club motions of 19 yips-affected golfers were compared to 224 unaffected experienced golfers (Marquardt, 2009). The kinematic analysis revealed a significant difference for the mean rate of clubface rotation at impact. Yips-affected golfers showed a lower rotation rate, yet significantly more inconsistency at the moment of impact with the ball. Additionally, the yips-affected group showed a more inconsistent clubface angle and arc of club path at impact. The results indicate that the yips movement can be associated with less consistent directional control of the clubface. However, the results were limited to parameters measuring only the golf club motion at the moment of impact with the ball. In another study, Adler and colleagues (2011) used a cyberglove to track the motion of the right hand of 17 yips-affected golfers and 33 unaffected golfers throughout the entire putting motion. Their results showed that the yips-affected golfers had more angular movement in wrist pronation/supination than unaffected golfers throughout the putting motion. Altogether it seems that the physical manifestation of the yips might be a pronation/supination motion of the wrist that results in more inconsistency of the clubface rotation rate, and thus, clubface angle at the moment of impact. Thus, the main visible characteristic of the yips appears to be the rotation of the wrist, and thus, clubface around the moment of impact with the ball.

However, based on the two aforementioned studies, it cannot be concluded with certainty that this rotation of the wrist indeed describes the physical manifestation of the involuntary movement component that is central to the definition of the yips (see chapter 4 for more detail). Both studies only employed between-subjects comparisons, and thus they only compared the average technical performance between two groups. Consequently, the differences that they found are not necessarily attributable to the yips, but could alternatively be related to general differences in the technical execution of a putt between the two groups of yips-affected and unaffected golfers. These possible technical differences might be consequences or antecedents of the yips symptoms, but not necessarily the physical manifestation of the involuntary movement. In order to identify the kinematic characteristics of the yips, it is necessary to employ a within-subjects design, and to create a situation in which participants perform the same putt with and without the yips (see Chapter 4).

In addition to the trouble with the between-subjects design of the two kinematic studies, both studies fail to report the frequency of the yips occurrence throughout their trials. If not all putts that are included in the mean parameters of the yips group are affected by the yips, then the results would be confounded. As Adler et al. reported, the yips did not occur on every putt throughout their experiment, a problem that is present in laboratory settings (Adler et al., 2011). The frequency with which the yips occurs in various settings, as well as its prevalence estimation, are addressed in the next paragraph.

1.5.3. THE FREQUENCY AND THE PREVALENCE OF THE YIPS IN GOLF PUTTING

The fact that the yips can have devastating effects on one's performance has already been illustrated. Yet, how often do the yips actually occur? The yips typically do not occur on every putt once a golfer is affected. Rather, the occurrence and severity of the yips seems to fluctuate (McDaniel et al., 1989; Smith et al., 2000). Sachdev (1992) reported that based on his investigation of 20 yips-affected golfers, the yips adds on an average 4.7 strokes per 18 holes. Across all studies investigating the yips depending on type of putt and the situation, it was found that the frequency and severity of the yips depends on the type of putt and the situation in which it is performed (McDaniel et al., 1989; Sachdev, 1992; Smith et al., 2000). Short putts ranging from 1 to about 8 feet are predominately affected by the yips, whereas longer putts are less often affected. Additionally, Smith and colleagues (2000) found that the majority of their participants reported experiencing the yips most often on downhill left-to-right breaking putts. Furthermore, across all studies participants reported that the yips occur most frequently in tournaments or other high-pressure situations such as taking an important putt, whereas the putting problems do not occur as frequently during practice (McDaniel et al., 1989; Sachdev, 1992; Smith et al., 2000). The literature does not provide any discreet numbers on how often the yips occur per certain number of putts, which is difficult to estimate due to the fluctuation of the yips occurrence. Somewhat easier, however, is the estimation of the percentage of yips-affected golfers in relation to all golfers.

The prevalence estimation of the yips in golf ranges from 28% when only based on the respondents to 12% when assumed that all non-respondents are unaffected. These estimations are based on 1050 questionnaires that were sent to professional and highly competitive golfers (McDaniel et al., 1989). Out of 360 returned questionnaires, 335 were used for further analysis and revealed that 93 (28%) participants reported being affected by the yips. In another study, the prevalence estimation ranged from 53.5% when only based on the selected respondents to 17.2% when assumed that all non-respondents are unaffected (Smith et al., 2000). These estimations are based on 2630 questionnaires, of which 1031 golfers responded, but only 846 were selected for further analysis, due to handicap restrictions of ≤ 10 strokes for men and ≤ 12 strokes for women. The authors of both studies raise the concern that the results might be confounded by an overestimation due to the invalidity of self-reports. Additionally, the estimations include only highly skilled golfers and thus do not cover the majority of golfers who are at a lower skill range. However, even the most careful estimations result in a relatively high prevalence rate compared with other movement problems (see chapter 3 for more details on this topic). Notwithstanding this high prevalence, little is known about the yips. In the following paragraphs we summarize what is known about the demographical, physiological, and psychological characteristics of yips-affected golfers.

1.5.4. THE DEMOGRAPHICAL CHARACTERISTICS OF YIPS-AFFECTED GOLFERS

Originally it was proposed that yips-affected golfers were slightly older and had more cumulative golf experience than their unaffected counterparts (McDaniel et al., 1989). This proposition, however, was based on a rather small sample of 335 golfers, and no significance test values were provided. On average, the yips-affected golfers were 50.5 (no *SD* available) and unaffected golfers were 47.5 (no *SD* available) years old. The mean golf experience of the yips-affected participants was 35.6 (*SE* = 1.3) years and 31.0 (*SE* = 0.8) years for the unaffected participants. In a more recent study which was based on a larger sample of 846 golfers, no significant differences in age or golfing experience were reported between yips-affected and unaffected golfers (Smith et al., 2000). The yips-affected golfers had a mean age of 45.2 (*SD* = 15.1) and a mean golf experience of 30.3 (*SD* = 14.1) years. The unaffected participants golfers had a mean age of 47.4 (*SD* = 14.6) and a mean golf experience of 30.7 (*SD* = 13.6) years. Based on this data, it does not seem that there are great differences in age or golfing experience between affected and unaffected golfers. Further demographic characteristics that were investigated were the age of the onset and the duration of the yips.

The yips-affected golfers' mean age of onset was only assessed in two studies, and was 35.9 years and 35.1 years, respectively (McDaniel et al., 1989; Sachdev, 1992). Participants first experienced the yips after playing for 20.9 years and 16.1 years, respectively. The duration of suffering from the yips was assessed by three studies and reported to range from 6 years (range 0.01 – 60; Smith et al., 2000) across 14.6 years (McDaniel et al., 1989) to 19.4 years (range 1 -39; Sachdev, 1992). These numbers show that the yips are a long-lasting problem and also indicate that the affected participants were highly experienced golfers before the onset of the yips. That the yips affect highly skilled and experienced golfers is generally documented in studies on the yips. The skill level of the yips-affected golfers is indicated in all other studies by the general golf experience and the handicap (*hcp*; a skill index in golf) of the participants (e.g., Adler et al., 2011; Adler, Crews, Hentz, Smith, & Caviness, 2005; Marquardt, 2009; Smith et al., 2003; Stinear et al., 2006). However, that the yips affect highly skilled golfers does not imply that novice golfers are not or cannot be affected. Most of the existing studies on the yips purposely selected highly skilled and experienced golfers to ensure that the putting problems are not due to insufficient skills. Therefore, novice golfers were actively excluded from the investigations of the yips. The study that is presented in chapter 3 of this dissertation is the first that includes the entire skill-range in its investigation of the yips prevalence and characteristics. In addition to the demographic characteristics of yips-affected golfers, physiological and psychological parameters have been investigated. The next paragraph presents a summary of the results.

1.5.5. THE PHYSIOLOGICAL CHARACTERISTICS OF YIPS-AFFECTED GOLFERS

A number of physiological parameters of yips-affected golfers have been measured and compared to unaffected golfers. Smith et al. (2000) found that the yips-affected golfers in their sample (n = 4) had faster mean heart rates while putting and exerted clearly more mean grip force while putting and while at rest than the unaffected golfers (n = 3). Additionally, the yips-affected golfers showed more peak muscle activity in the left elbow flexor and the left wrist flexor and extensor muscle groups than the control group while putting. No significant differences, however, were found in the muscle groups of the right arm. Similar results were found in another study, in which a subsample (n = 8) of yips-affected golfers showed more peak muscle activity than the control group (n = 9) only in the left wrist extensor (Stinear et al., 2006). Further investigations of the muscle activity in yips-affected golfers found that 5 out of 10 yips-affected golfers had co-contractions of extensor and flexor muscles while putting, whereas none of the 10 control participants had any co-contractions (Adler et al., 2005). However, in a more extended investigation of co-contractions in yips-affected golfers, the results revealed that there was no significant difference in the number of co-contractions between affected and unaffected golfers (Adler et al., 2011). Although a trend for more co-contractions in the affected group was found, the unaffected group occasionally also showed co-contractions of wrist extensor and flexor muscles while putting.

In addition to physiological measurements taken during the execution of a putting task, a number of tests have been employed to investigate general physiological differences between yips-affected and unaffected golfers. Sachdev (1992) compared the grip strength, visuomotor coordination, and mental and motor speed of 20 yips-affected golfers with 20 unaffected golfers (Sachdev, 1992). None of these tests revealed any significant differences between the groups, indicating that the aforementioned physiological differences are likely to be task-specific.

To date, it is not clear what the physiological differences between yips-affected and unaffected golfers mean for the understanding of the yips. The postulated interpretations of the results are discussed in the section on the underlying mechanisms of the yips. Moreover, especially the interpretation of the EMG results and the diagnostic value of EMG measurements in analyzing the yips are investigated and discussed in detail in chapter 4. In addition to the examination of physiological differences between yips-affected and unaffected golfers, a number of psychological factors have also been investigated and are addressed in the next section.

1.5.6. THE PSYCHOLOGICAL CHARACTERISTICS OF YIPS-AFFECTED GOLFERS

The investigation of psychological factors in research on the yips has particularly focused on anxiety. This is not surprising, given the early reports by yips-affected golfers that the symptoms and frequency of the yips become more severe in stressful situations such as tournaments (McDaniel et al., 1989). However, despite these reports, no differences between yips-affected and unaffected golfers emerged from standardized psychometric questionnaires testing trait (i.e., Spielberger's Trait Anxiety Scale, STAI) and state anxiety (i.e., Competitive State Anxiety Inventory, CSAI-2; Sachdev, 1992; Stinear et al., 2006).

An additional psychological factor that has been investigated is obsessional thinking. McDaniel et al. (1989) found a higher score for yips-affected golfers than unaffected participants on one item, reflecting obsessional thinking. Yet, no significant difference in obsessional thinking was found between the two groups according to psychometric measurements (i.e., Leyton Obsessional Inventory, LOI; Sachdev, 1992).

A number of other psychological factors such as personality have also been compared between yips-affected and unaffected golfers using various psychometric tools (for a complete list see Sachdev, 1992). Yet, no differences were found on any of these measurements. Therefore, we will not further discuss all of these results, and will instead turn to the underlying mechanisms of the yips in the next section.

1.5.7. THE UNDERLYING MECHANISMS OF THE YIPS IN GOLF

The underlying mechanisms causing the yips in golf putting are not well understood. Two main explanations, a neurophysiological one and a psychological one have been proposed in the scientific literature. Currently, both explanations are integrated into a model that proposes each one on opposing poles of a continuum (Smith et al., 2003). In the following, we will first discuss each explanation separately and subsequently discuss the continuum model.

1.5.7.1. A neurophysiological explanation of the yips in golf putting

Originally, the yips were considered a golfer's cramp in reference to other movement disruptions such as writer's cramp or musician's cramp, which are collectively called occupational cramp (McDaniel et al., 1989). Occupational cramps can affect all sorts of movements that require finely coordinated movements that are performed in repetitive fashion and under demands for precision (e.g., playing an instrument; Byl, 2006). Occupational cramps are also known as task-specific focal dystonias (TSFD). These are excessive involuntary muscle contractions (thus, dystonia) restricted to one body part (thus, focal) that affect the body parts that are mainly involved in highly trained skills (e.g., the fingers of a pianist; Torres-Russotto & Perlmutter, 2008). TSFDs can affect various body parts from head (e.g., embouchure dystonia; 16) to toe (e.g., runners dystonia; Leveille & Clement, 2008) depending on the task, but most commonly affected is the upper body (Torres-Russotto & Perlmutter, 2008). The symptoms are usually limited to the affected task and initially do not affect other similar tasks (Sheehy & Marsden, 1982). However, it is possible that the symptoms spread to other tasks and body parts as well (Weiss et al., 2006).

TSFDs are typically a primary adult-onset dystonia (>28 years of age) and usually first occur between the third and sixth decade of life (Karp, 2007; Sheehy & Marsden, 1982). The prevalence rate of primary focal dystonias in the general population is estimated between 0.01% and 0.03% (Fukuda, Kusumi, & Nakashima, 2006; Nutt, Muenter, Aronson, Kurland, & Melton, 1988) and in the specific population of musicians between 0.5% and 1% (Altenmueller, 2003; Frucht, 2004).

As possible risk factors for developing a TSFD, a family history of TSFDs has been identified in 10% to 20% of the patients (Waddy, Fletcher, Harding, & Marsden, 1991). Yet, it is known that the accuracy of patients' reports about family history is poor (Martino et al., 2004). Another likely risk factor is the overuse or overlearning of the affected movement. This is indicated by the affliction of only highly skilled movements. Moreover, in musician's cramp, usually the body part with the highest workload is affected (Altenmueller & Jabusch, 2009). Furthermore, it was shown that adult monkeys develop dystonia-like symptoms after repetitively performing a strictly controlled grasping task more than 1000 times. Yet, many other people who perform repetitive tasks in controlled environments do not develop a TSFD; hence, there must be something else causing the TSFD (Torres-Russotto & Perlmutter, 2008). Unlike the paucity of findings on the risk factors, a large volume of research has focused on the causes of TSFDs. Although the exact causes remain unclear, it seems clear that the reasons for TSFD are multifactorial. Discussing these findings in detail is beyond the scope of this dissertation. However, to sketch a sound picture of the state of the art of TSFD, we will summarize the great work of Torres-Russotto and Perlmutter (2008) briefly.

In a recent review on TSFD, Torres-Russotto and Perlmutter (2008) organized the findings on the pathophysiology of TSFDs into (a) regional pathophysiology, (b) loss of inhibition, (c) excessive plasticity, and (d) changes in sensory function.

(a) regional pathophysiology. Regional pathophysiology can be divided into structural abnormalities and functional abnormalities. Structural abnormalities in patients with TSFD were mostly apparent in lesions of the basal ganglia, a region which, amongst others, is associated with voluntary motor control. Additionally, an increase in grey matter in several brain areas such as the prefrontal cortex, primary sensorimotor cortex, thalamus, and cerebellum were found across a number of studies. The increase was found in areas that are associated with the body part that is affected by the TSFD, such as the sensorimotor cortex of the hand in patients with focal dystonia of the hand.

Besides abnormal structures, abnormal functions of various brain areas have been found in patients and might also contribute to the etiology of TSFD. Yet, the problem with interpreting the findings is that it is not clear if the differences that were found between patients and controls cause the motoric symptoms or rather reflect feedback from the altered motor behavior in dystonic patients. Imaging brain functions while a person is at rest also does not solve the problem, because TSFDs are usually not present at rest. In an attempt to avoid this potential confounder, one study analyzed only imaging data from right after the motor activity stopped and found that abnormal signals in the striatum persisted after the task stopped (Blood et al., 2004, cf. Torres-Russotto & Perlmutter, 2008). Another study analyzed data only from trials during which no dystonic symptoms occurred and found lower activation of the primary sensorimotor and the premotor area (Haslinger et al., 2005, cf. Torres-Russotto & Perlmutter, 2008). However, as Torres-Russotto and Perlmutter criticize, both studies did not assess the muscle activity to control for the absence of abnormal motor activity.

In sum, a number of differences in brain functions have been found between patients with TSFD and healthy controls. Whether these differences are an underlying cause of the motor symptoms or just the consequences of the motor symptoms remains unclear. Torres-Russotto and Perlmutter (2008) summarize their review of the regional pathophysiology in TSFD as such: "current evidence demonstrates defects in basal ganglia pathways that may reflect or include dysfunction of dopaminergic pathways that influence basal ganglia cortical circuits. The role of other pathways, like cerebellum or other biomechanical systems, is less certain" (p. 188).

(b) loss of inhibition. Besides abnormalities in brain structures and functions, the loss of inhibition in patients with TSFD was found on subcortical, cortical, and spinal levels. The loss of abnormal intracortical inhibition might lead to a reduced specificity in the output from the cortex. Additionally, it was found that the surrounding inhibition of somatosensory evoked potentials was reduced in patients with dystonia, indicating that the sensory integration of afferent stimulation is abnormal. The abnormal inhibition in patients with TSFD might explain the involuntary activation of muscles that result in the typical symptoms of TSFD. However, it is also possible that the loss of inhibition is a consequence of dystonia rather than a cause.

(c) excessive plasticity. Another potential cause of TSFD might be the excessive plasticity of the brain. The usually repetitive nature of the tasks affected by TSFD might lead to an alteration of the pathways in the brain, which has been shown to be a consequence in primates performing repetitive tasks (Byl, Merzenich, & Jenkins, 1996). In patients with TSFD, a few findings suggest an increased plasticity of the brain and an enlargement of cortical responses to nerve stimulation beyond the

innervated muscles (cf. Torres-Russotto & Perlmutter, 2008). The excessive plasticity of the brain might lead to the aforementioned abnormalities in the structures and the functions of the brain. However, it is not clear if the increased plasticity is a consequence or antecedent of dystonia.

(d) changes in sensory functions. The sensory functioning in patients with TSFD seems to play an important role in understanding TSFDs. It has long been known that the alteration of sensory inputs can attenuate the symptoms of focal dystonia, which is referred to as *sensory trick*. For instance, playing the piano with latex gloves reduced the symptoms of patients with pianist cramps; touching the mouth also reduces symptoms of embouchure dystonia (Altenmueller & Jabusch, 2009). Furthermore, research suggests that the sensory perception and integration of patients with TSFD is impaired. For example, spatial and temporal discrimination of cutaneous sensory input is deficient. Moreover, a reduction in sensorimotor cortex blood flow as a response to vibration stimulation shows defective sensory processing on a central level. Torres-Russotto and Perlmutter (2008) suggest that the sensory fields in the sensorimotor cortex may broaden as a consequence of repetitive actions, as has been shown in animal models by Byl et al. (1996). The broadening and overlapping of sensory fields can be associated with overflow and less differentiation during motor activities. Yet again, if these changes in sensory functions are an antecedent or the consequence of TSFD is not clear. However, based on their reviewed studies, Torres-Russotto and Perlmutter (2008) suggest that, “there is a baseline sensory abnormality in patients with dystonia” (p. 192). Moreover, they write that, “several lines of evidence suggest that this may be the key part of the pathophysiology of the condition” (p. 192).

In sum, the underlying mechanisms of TSFD remain unclear. There is evidence for altered brain structures and functions as well as excessive plasticity of the brain. Additionally, there is a loss of inhibition on cortical and spinal levels and a deficient sensory perception and integration. If all these abnormalities, however, are antecedents or consequences of the dystonia is still unclear.

The reason why the yips in golf were originally postulated to be a form of TSFD was mainly based on participants’ reports about similar characteristics, such as a spontaneous onset of involuntary contractions affecting only a specific body part while performing a highly trained specific task that was previously unaffected (McDaniel et al., 1989; Sachdev, 1992). Additionally, the higher peak EMG activity and co-contractions that were found in yips-affected golfers more recently (see chapter 1.4.5.) were also interpreted as support for the postulation that yips are a specific form of TSFD (Adler et al., 2005, 2011; Smith et al., 2000; Torres-Russotto & Perlmutter, 2008). The higher EMG activity was argued to be a possible consequence of the reduced inhibition that is typical in TSFDs (Stinear et al., 2006) and the co-contractions are regarded as a hallmark of focal dystonias (Adler et al., 2005, 2011).

However, the interpretations of these findings about the yips are rather ambiguous. First of all, it is noteworthy that not all TSFDs seem to have the exact same etiology. Rosenkranz et al. (2005) compared the short-latency intracortical inhibition (SICI) between patients with musician's cramp and writer's cramp, using transcranial magnetic stimulation (TMS) and vibration stimulation of the fingers. Their study showed that both patient groups had abnormal sensorimotor integration patterns, but only the patients with musician's cramp showed strongly reduced SICI in the hand muscles. Hence, simply because the yips are task-specific and involuntary does not necessarily mean that they have the same etiology as other TSFDs. Moreover, there are a number of indications and alternative interpretations of aforementioned findings that support the assumption that the yips might be caused by other reasons than TSFDs. In the following, we briefly illustrate these indications and refer to the corresponding chapters in this dissertation dealing with the respective topics in greater detail.

One indication for the yips possibly being caused by other reasons than typical TSFDs like the musician's cramp is the very high prevalence of yips in golf (up to 17.2% carefully estimated; see chapter 1.4.3.) compared to the TSFDs in musicians (up to 1%; Altenmueller, 2003), for example. Furthermore, it is not clear if the yips actually only affect highly skilled movements. The investigations and reports about yips so far have focused only on experienced golfers to ensure that the yips were acquired. In chapter 3, we address these issues and assess the prevalence of yips across the entire skill range in golf.

Another reason suggesting that the yips might not be, at least not only, a typical form of TSFD is the finding that the yips appear to manifest most often in fast jerking movements, whereas in musician's and writer's cramp the involuntary component usually manifests in cramps and abnormal postures (Jabusch & Altenmueller, 2009; McDaniel et al., 1989; see also chapter 4). A further ambiguity lies in the interpretation of the EMG results. It is not clear if the higher EMG activity is due to the yips or rather a consequence of compensating behavior of the unaffected hand, because differences were only found in the left arm, yet the yips more often occur in the dominant arm (see chapter 3 & chapter 4). Moreover, co-contractions can also be observed in unaffected golfers and are sometimes used as a naïve strategy to stabilize a joint; thus, merely finding co-contraction in yips-affected golfers does not allow the unambiguous conclusion that the yips are TSFD. In chapter 4, we address the issue of physical manifestation and the diagnostic value of EMG measurements in greater detail.

To summarize, TSFDs are involuntary disruptions of highly-skilled and previously unaffected finely-coordinated movements. The causes of TSFD are believed to be of neurophysiological nature. A few studies have proposed that the yips in golf are a form of TSFD, yet no empirical findings unambiguously support this notion and alternative explanations are plausible. One such explanation is presented in the following section.

1.5.7.2. A psychological explanation of the yips in golf putting

Some scientists propose that the yips are psychologically caused (e.g., Masters & Maxwell, 2008; Smith et al., 2003; Wegner, 2009). For example, Smith et al. (2003) postulated that a severe form of performance anxiety might cause the yips, and proposed that the yips might underlie the same mechanisms as choking under pressure. The concept of choking in sport was recently redefined by Hill, Hanton, Fleming, and Matthews (2009) as “a process whereby the individual perceives that their resources are insufficient to meet the demands of the situation, and concludes with a significant drop in performance – a choke” (p. 206). Notably, a choke is different from other performance failures such as a slump or a panic. Whereas a slump extends over a certain period, a choke is a discrete performance failure. A choke also differs from a panic in that a panic is characterized by the inability to think rationally under pressure, whereas the athlete is able to think rationally whilst choking (Hill et al., 2010). A large body of research has been dedicated to understanding the underlying mechanisms of this significant and discrete drop in performance under pressure (for reviews see Beilock & Gray, 2007; Hill et al., 2010). Several theories have been proposed and can be classified in two main categories – The drive theories and the attentional theories (Hill et al., 2010).

Drive theories commonly propose that choking is directly related to the level of arousal that the person experiences. The Inverted U Theory suggests that the optimal zone of arousal to perform at one's best is somewhere at a moderate level (Yerkes & Dodson, 1908). Too low or too high levels of arousal result in suboptimal performance. Another theory suggests that high levels of arousal will cause a person to produce whatever their dominant response in that situation would be (Zajonc, 1965). In experts, this Dominant Response Theory would predict a performance enhancement under levels of high arousal, whereas in novices levels of high arousal would result in performance deteriorations. Drive theories have been criticized on the basis that they cannot account for all instances where people and especially experts choke under high pressure (Baumeister & Showers, 1986). Furthermore, it has been mentioned that drive theories fail to fully explain the underlying mechanisms that lead to choking (Beilock & Gray, 2007). This could be one reason why current research on choking has mainly focused on attentional theories.

Attentional theories can also be divided into two main underlying mechanisms that have been proposed to explain choking under pressure. One explanation states that choking under pressure occurs because high levels of anxiety will lead to distracting thoughts and worries that occupy a person's working memory, and thus distract the person from processing task-relevant information. Consequently, this distraction leads to a drop in performance. The most prominent theory advocating this explanation is the Processing Efficiency Theory (Eysenck & Calvo, 1992, see also Wine, 1971), stating that the inefficient processing of task-relevant information due to distracting thoughts can be overcome by increased effort. Yet, once a sufficiently high level of anxiety is reached, solely increased effort is not enough to stabilize the performance and choking occurs.

The second explanation for choking based on attentional mechanisms centers around the inwardly directed focus of attention (e.g., a focus on one's hands while performing a golf putt). Generally, theories postulating mechanisms of self-focus as explanations for choking suggest that performance anxiety will cause the person to become self-conscious and focus inwardly on the execution of the skill that is relevant for the accomplishment of the task (Hill et al., 2010). This inwardly directed focus on the execution of a skill can lead to choking while executing skills that are well-trained. According to the stages of learning model from Fitts and Posner (1967), well-trained skills are unconsciously processed outside of working memory. When a person focuses on the execution of these well-trained skills, the information processing becomes conscious and occurs within the working memory. This explicit processing of the skill leads to less capacity for task-relevant information processing in working memory. Moreover, it breaks down the automatic execution into its explicit parts, which make the execution more vulnerable to mistakes (Masters & Maxwell, 2008) and eventually might lead to choking. Importantly, this mechanism only affects well-learned tasks that became part of procedural memory (Hill et al., 2010).

Two self-focus theories have received the main attention in the choking literature and inspired numerous studies. The first is the Explicit Monitoring Hypothesis (EMH) from Beilock and Carr (2001). The other is the Conscious Processing Hypothesis (CPH) or Reinvestment Theory (Masters, 1992; Masters & Maxwell, 2008). Both theories differ from each other in the way that the EMH proposes that the mere monitoring of the skill execution can lead to the above described process and thus choking, whereas the CPH states that the attempt to consciously control the skill execution eventually leads to choking.

Currently, it is still a matter of debate whether self-focus or distraction theories account best for choking under pressure (Hill et al., 2010). The answer probably depends on a number of moderating variables (see Hill et al., 2010 for an overview). For example, it has been suggested that the self-focus theories probably best account for choking on tasks that require mostly procedural knowledge, such as sensorimotor tasks (e.g., golf putting). Contrarily, tasks that require mainly declarative knowledge, such as cognitive tasks, are more prone to choking by mechanisms of distraction. Additionally, the task properties and the properties of the pressure-inducing situation seem to have an interacting effect on the occurrence of choking. DeCaro, Thomas, Albert, and Beilock (2011) showed that pressure that is induced by striving for a certain outcome leads to a performance decrement on tasks requiring declarative skills (i.e., rule-based category learning). Contrarily, pressure that is induced by performance monitoring through videos or observations seems to lead to a performance decrement on tasks requiring procedural skills (i.e., information-integration category learning). It seems that both distraction and self-focus theories account for choking, depending on the situation the person is in. However, all of the aforementioned studies on choking manipulated the focus of attention experimentally, and therefore lack ecological validity. Thus, despite the demonstrations of different processes that might explain choking, it is unclear what athletes really focus on in competitive situations. Since the most typical situation for choking to occur is during competitions, it seems reasonable to investigate what athletes focus on during competitive situations. Oudejans, Kuijpers, Kooijman, and Bakker (2011) retrospectively assessed the thoughts and attention of 70 athletes from 19 different kinds of sports during competitive situations. Their results showed that the athletes reported significantly more thoughts about worries (28.9% of all reported thoughts) than thoughts about movement execution (4.1%). The authors concluded that despite the experimental support for self-focus theories, more ecologically valid methods tend to instead support distraction theories as an explanation for choking.

To summarize, choking is a significant and discrete drop in performance in a situation in which the person experiences pressure to perform well. Currently, attentional theories offer explanations for the underlying mechanisms causing the choke. It seems that distracting thoughts as well as a focus on the movement execution can cause a person to choke, depending on the skill level, task properties, and the properties of the pressure-inducing situation. To understand the exact relationship between these and other moderating variables, further research is required.

The reason why some authors argue that the yips in golf are a form of choking lies mainly in the reports that the symptoms become more severe in stressful situations, such as taking an important putt, and the reports that the yips most often occur for the first time during tournaments (McDaniel et al., 1989; Smith et al., 2003). However, despite these personal reports, no significant differences between yips-affected and unaffected golfers have been found on standardized anxiety inventories (Sachdev, 1992). However, it is possible that regardless of the similarities in anxiety, yips-affected golfers react differently in pressure situations and, for instance, focus more inwardly. Given the important role that the focus of attention apparently plays in explaining choking under pressure, it is surprising that no study that we are aware of has investigated what yips-affected golfers focus on while putting. Therefore, we addressed this topic in chapter 2.

1.5.7.3. A continuum model between focal dystonia and choking for the yips in golf

The most recent theoretical perspective on the yips in golf combines the neurophysiological and psychological explanation of the underlying mechanisms. Smith et al., (2003) were the first to propose that the reasons for the yips lie on a continuum between TSFD on one end and choking under pressure on the other end.

Their postulation is based on the same arguments for the yips being a TSFD and a form of choking, respectively, that we have mentioned before. Yet additionally, they asked 72 yips-affected golfers about their personal perception and definition of the yips. The answers were either categorized as Type 1 yips (i.e., focal dystonia as the reason for yips) or Type 2 yips (i.e., choking as the reason for yips). When participants' descriptions focused on physical symptoms (e.g., "last second jerk of the club and turn of face of the putter"; p. 24) the authors categorized them as Type 1 yips-affected golfers. When participants' answers focused on descriptions of psychological distress (e.g., "inability to make simple short putts when you need to, as if paralyzed"; p. 25) they were categorized as Type 2 yips-affected golfers. Additionally, some responses were related to both physical and psychological symptoms (e.g., "Tighten up and your stroke gets short and choppy. Sometimes you flinch"; p. 25) and thus the authors concluded that this group was somewhere between Type 1 and Type 2 yips on a continuum.

A few authors supported the continuum model. Adler et al. (2005) argued that only half of his yips-affected golfers showed co-contraction (i.e., possibly a sign of focal dystonia), and therefore the yips symptoms of the other half were probably due to some other cause – potentially choking. To date, only one study has attempted to directly test the continuum model (Stinear et al., 2006). Although the authors conclude that their results support the continuum model, we argue that their outcome is rather ambiguous. A detailed discussion of Stinear and colleagues' study is presented in chapter 2. Briefly stated, we argue that their study does not provide evidence for the continuum model, because there were no differences between Type 1 and Type 2 yips-affected golfers in EMG activity, level of inhibition, or levels of anxiety. Furthermore, the differences that were found between the Type 1 group and the control group were possibly related to the age differences between the groups. Conclusively, as unclear as it is whether the yips are a form of TSFD or a form of choking, it is not clear whether different types of yips in golf putting exist, or whether these types interact with each other. Moreover, there is currently no valid method for diagnosing either type of yips. This unclear etiology of the yips is certainly one reason for the lack of effective methods to cope with the yips in golf putting, as will be discussed in the next section.

1.5.8. INTERVENTIONS AND COPING MECHANISMS FOR THE YIPS IN GOLF PUTTING

"Once you got 'em, you always have 'em" is a quote about the yips often assigned to Tommy Armour, the father of the term yips. To this day, more than half a century later, this quote still seems to have some truth to it. Although there are reports about spontaneous remedies (McDaniel et al., 1989), there is still a great paucity of effective and reliable interventions. Naïve strategies by affected golfers include changes of the grip (e.g., crosshanded), switching the side of the stance, or changing the equipment (e.g., broomstick putter; Smith et al., 2003). These strategies often reduce or even eliminate the symptoms initially, but usually are not long-term remedies (McDaniel et al., 1989; Smith et al., 2003). Rather, these strategies are a way to circumvent the problem instead of actually curing the yips. Attempts to cure the yips without changing the technique or equipment are rare. Yet, a few efforts have been published.

One promising approach was introduced by Bell and colleagues (see Bell, Skinner, & Fisher, 2009; Bell, Skinner, & Halbrook, 2011), who applied a mental imagery technique called Solution Focused Guided Imagery (SFGI) to yips-affected golfers. The central principle of this technique is to "create vivid images of themselves thinking, feeling, and behaving in ways devoid of their problem" (Bell et al., 2011, p. 3). Performing SFGI 15 minutes prior to each round of golf eventually freed the participants from their symptoms. Even at a retention test 12 to 14 weeks later, most participants remained yips-free (Bell et al., 2011). The work by Bell and colleagues offers an interesting and promising new approach to treating the yips in golf. However, further investigations are necessary to allow certainty about the effectiveness of this kind of treatment. Currently, only a total of eight golfers were investigated across three studies. Moreover, no control group has been implemented in the research design, thus not allowing the conclusion that the positive effects are a consequence of SFGI or merely the attention from the researchers and/or golfers' motivation to solve their problem. Furthermore, although retention tests have been included recently (Bell et al., 2011), no assessments of the yips have been conducted in explicit pressure situations such as tournaments; thus, it is not clear if the symptoms have been eliminated completely. The assessment of the yips is another critical aspect of the studies. The putts were videotaped to assess the occurrence of yips, yet it is not explicitly mentioned what observation would classify as a yips putt versus a yips-free putt. Moreover, the reader is not informed about the rating procedure (e.g., how often the videos were watched), nor the video material and quality (e.g., the resolution, or playback speed). Yet, this is an essential point in observations of potentially fast and small-scale movements (see Chapter 4).

Another aspect that needs further investigation is the authors' claim that they have investigated Type 1 yips golfers (Bell et al., 2011). We argue that the type of yips is still impossible to assess at present (see chapter 1.4.7.3). Yet, it is important to understand more about the potential underlying causes of the yips. Depending on the causes, it would be possible to tailor interventions that have been shown to be effective in treating TSFDs or choking. For example, TSFDs are often treated medically with levodopa or Botulinum toxin injections (Jabusch & Altenmueller, 2006). Alternatively, re-training of the affected movement, learning-based sensorimotor training, immobilization, or constraint-induced training can result in symptom-free performance of the re-learned movement (Jabusch & Altenmueller, 2006). However, the effects of these treatments are not yet well established and above all, these are all very time-intensive therapies that require a strong commitment and patience. If the underlying cause of the yips is more in line with the mechanisms causing choking under pressure, then treatments for the yips should rather focus on directing the focus of attention away from worries or the explicit movement execution. For example, implicit learning, self-awareness training, and the use of secondary tasks are promising approaches to preventing choking under pressure (e.g., Hill et al., 2010; Land & Tenenbaum, 2012). Which treatment will be most promising strongly depends on the underlying causes of the yips in golf putting. In the next section, we introduce how the present dissertation contributes to a better understanding of the yips.

1.6. Aim of The Dissertation and Research Questions

By now it should be clear that the yips in golf putting can be devastating for one's performance and sometimes even their professional career. It seems that the yips are fairly widespread across highly skilled golfers. Yet, despite its prevalence and its impact on performance, there is a paucity of reliable interventions to cope with the yips in golf putting. One reason for the lack of interventions is certainly the unclear etiology of the yips. The purpose of this present dissertation is to enhance the understanding of the etiology of the yips in golf putting. This is not only crucial to eventually being able to consult yips-affected golfers on how to cope with the yips, but also to promote our general understanding of motor control and especially its disturbances.

The research in this dissertation focuses on psychological, behavioral, and physiological aspects of the yips in golf putting. Furthermore, it provides alternative suggestions of potential underlying causes of the yips in golf putting. Last but not least, the dissertation provides the first scientifically developed diagnostic criteria and a procedure to objectively assess the yips in golf putting.

More specifically, in chapter 2 the psychological components of the yips in golf are addressed. Although it has been suggested that the yips might be a form of choking, to date no investigations of the thoughts and focus of attention of yips-affected golfers have been published. Given the importance of attention and arousal in explaining choking, we conducted an interview study to investigate the thoughts, feelings, and focus of attention in yips-affected golfers. Based on the aforementioned continuum model, we expect the yips-affected golfers to mainly focus on worries or the movement execution when having to take a putt.

In chapter 3, the suggestion that predominately highly skilled golfers are affected by the yips is addressed. This suggestion is one of the main reasons for the postulation that the yips might be a form of TSFD, because TSFDs usually affect highly trained skills. However, as has been pointed out above, it is not known whether relatively untrained golfers also experience the yips, because to date only professional and highly competitive golfers have been investigated. Therefore, we designed an online questionnaire to assess the prevalence of yips in golf across the entire skill range. Based on the suggestion that the yips are a form of TSFD, we expect that only highly experienced golfers are affected by the yips. In addition to the prevalence and the characteristics of the yips, we also assessed which other movements are affected by yips-like symptoms. The results motivated a subsequent online inquiry, investigating the sports history of a subsample of the first questionnaire. Based on the results, we propose a possible relationship between the yips in golf and certain sports histories.

In chapter 4, we address the behavioral and physiological components of the yips in golf putting. Specifically, we address the paucity of an objective diagnosis of the yips. We present a biomechanical analysis of the yips in golf putting to identify the physical manifestation of the yips in putting. Using kinematic analyses, we establish the first objective diagnostic criteria to distinguish yips-affected putts from unaffected putts. This allows for measuring the yips in putting. Furthermore, we present a procedure that allows for the diagnosis of the yips in putting, as well as reliably provoking the yips in laboratory settings. This is especially valuable for future studies on the yips which aim to assess the effectiveness of interventions or the effect of experimental manipulations. Additionally, the diagnostic value of using EMG measurements, a broadly applied measurement in the scientific literature on the yips, was tested and discussed in this chapter. We conclude this chapter with a revised definition of the yips in golf putting and recommendations for how to diagnose the yips in future studies as well as on the golf course.

In chapter 5, we summarize and discuss the most relevant findings presented in chapters 2 to 4 in a broader context of the potential underlying mechanisms of the yips in golf putting. Moreover, we embed these findings into a broader perspective on motor control, and additionally suggest a new explanation of the yips. Finally, we conclude the chapter with an outlook on further research.

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2. CHAPTER – UNDERSTANDING THE YIPS IN GOLF: THOUGHTS, FEELINGS, AND FOCUS OF ATTENTION IN YIPS-AFFECTED GOLFERS

This chapter is based on:

Philippen, P. B., & Lobinger, B. H. (2012). Understanding the yips in golf: Thoughts, feeling, and focus of attention in yips-affected golfers. *The Sport Psychologist, 26*, 325-340.

2.1. ABSTRACT

The yips in golf is the interruption of a smooth putting movement by an involuntary jerk or freezing of the arm. Psychological factors seem to worsen the phenomenon. However, published data on how the yips in golf is cognitively and emotionally experienced are very limited. Moreover, the focus of attention in yips-affected golfers has not been investigated. Thus, we interviewed 17 yips-affected golfers to record the thoughts and feelings that are experienced in a situation in which the yips occurs. Additionally, we asked them about their focus of attention right before putting. Content analysis revealed a negative cognitive and emotional pattern for all golfers. Furthermore, 11 participants reported focusing either internally or on possible mistakes. The results contribute to an understanding of the yips in golf and provide a starting point for further investigations into possible interventions for the yips.

2.2. INTRODUCTION

> *I was 18 years old when I won my first tournament on the European Tour. That's where I first developed "the yips." This is a jerky, uncontrolled putting stroke that sends scores soaring. All of my career I've struggled to control the yips. At one point I was yipping so badly that I four-putted from three feet and actually hit the ball twice. Those were extremely difficult times. I often thought about quitting….*
> (Langer, n.d.).

Bernhard Langer, a member of the World Golf Hall of Fame and two-time winner of the Masters, was describing a phenomenon in sports known as the yips. The yips can be defined as an involuntary muscle contraction that manifests in jerks, tremors, or freezing of a planned movement (Smith et al., 2003). Although there are also reports of yips-like phenomena in darts and cricket (Bawden & Maynard, 2001), most knowledge about the yips comes from studies in golf (e.g., Adler, Crews, Hentz, Smith, & Caviness, 2005; Smith et al., 2003; Stinear et al., 2006), where it often affects the putting stroke. The smooth putting movement is typically interrupted by a jerk and/or freezing in the forearms or hands prior to impact, sending the ball to an unpredictable destination (Sachdev, 1992).

The estimated prevalence of the yips in golf varies greatly. McDaniel, Cummings, and Shain (1989) reported that 26% of all respondents to their questionnaire had experienced the yips. More recently, Smith et al. (2000) reported that 53.5% of all respondents with a low handicap (female <12 and male <10) had experienced the yips. A prevalence estimation including the nonrespondents of the study revealed a prevalence range of 32.5% (assuming that 25% of the nonrespondents had experienced the yips) to 47.5% (assuming that 50% of the nonrespondents had experienced the yips) for low handicap (<12) golfers.

Despite the high prevalence, the etiology of the yips is still unclear. Some authors have suggested that the yips is a form of task-specific focal dystonia (e.g., Adler et al., 2005; McDaniel et al., 1989; Sachdev, 1992), which is a neuropathological movement disorder often affecting fine-coordinated movements that are intensively and repetitively practiced, such as playing an instrument (e.g., musician's cramp; for a review see Jabusch & Altenmueller, 2006), and is sometimes also referred to as occupational cramp (e.g., Byl, 2006). Others have suggested that the yips might be a chronic form of choking (e.g., Masters & Maxwell, 2008), which is a performance deterioration as a response to a situation of experienced high pressure (see Beilock & Gray, 2007; Hill, Hanton, Matthews, & Fleming, 2010, for reviews on choking). Further still, some have suggested that the yips might exist on a continuum between focal dystonia (Type 1 yips) and choking (Type 2 yips; Smith et al., 2003; Stinear et al., 2006).

Smith et al.'s (2003) initial attempt to distinguish Type 1 from Type 2 yips-affected golfers was based on the golfers' subjective perceptions or definitions of the yips. These were categorized as Type 1 yips when they focused on physical characteristics (e.g., "last second jerk of the club and turn of face of the putter"; p. 24) or as Type 2 yips when they focused on descriptions of psychological distress (e.g., "inability to make simple short putts when you need to, as if paralysed"; p. 25). Additionally, some responses were related to both physical and psychological symptoms (e.g., "Tighten up and your stroke gets short and choppy. Sometimes you flinch"; p. 25) and thus the authors concluded that this group was somewhere between Type 1 and Type 2 yips on a continuum.

In an attempt to test the continuum model, Stinear et al. (2006) employed behavioral (inhibition task), physical (EMG measurements), and psychological (state anxiety scores) measurements to compare groups that were categorized as Type 1 yips, Type 2 yips, or unaffected golfers, following the procedure from Smith et al. (2003). All participants putted under a low- and a high-pressure situation while the outcome and the muscle activity of both arms were recorded. Stinear et al. hypothesized that the Type 1 yips group would show greater muscle activity while putting and more errors on a behavioral inhibition task than the Type 2 yips group and the unaffected group. This would be because patients with focal dystonia have shown impaired inhibitory function on several levels of the central nervous system (Torres-Russotto & Perlmutter, 2008) and on behavioral responses (cf., Stinear et al., 2006), which results in higher muscle activity and more errors on a behavioral response inhibition task than in control groups. Additionally, because of the strong association between choking and performance anxiety, the authors expected the Type 2 yips group to show generally higher cognitive state anxiety levels and stronger performance impairment under the high-pressure situation as compared with the unaffected and the Type 1 yips groups. Finally, it was expected that once the chance to earn a monetary reward was removed all groups would improve their putting performance.

The results supported the hypotheses only partially. The Type 1 group exhibited higher peak muscle activity in the left arm as well as more errors on the inhibition task as opposed to the unaffected group. There were, however, no differences between the Type 1 and Type 2 groups in muscle activity or error scores. Additionally, contrary to the predictions, the Type 2 yips group did not differ in the general level of cognitive state anxiety. Furthermore, the high-pressure condition did not affect the outcome of the Type 2 group. Yet, when the chance to earn a monetary reward was removed, only the Type 2 group and the unaffected group improved their outcome score.

Stinear et al. (2006) concluded that their study provided evidence for the model of two different types of yips. In contrast to what was hypothesized, however, the results also show that there were no differences between the Type 1 and Type 2 groups on a number of measurements. Thus, although it is certainly possible that the two types of yips are caused by different underlying mechanisms, it remains unconfirmed whether the Type 1 yips are caused by focal dystonia and the Type 2 yips by choking. Despite the potential usefulness of categorizing the yips into different types, there is no validated procedure to do so at this point.

Notwithstanding the unclear etiology, most authors acknowledge the detrimental effects of psychological factors such as stress and anxiety. For instance, focal dystonia symptoms are worsened by anxiety (e.g., Altenmueller & Jabusch, 2009; Smith et al., 2003) and choking, by definition, requires the perception of a high-pressure situation (e.g., Beilock & Gray, 2007; Hill et al., 2010). The influence of psychological pressure on the yips is also indicated by the fact that the majority of golfers who experience the yips do so most often in pressure situations, such as tournaments (McDaniel et al., 1989; Smith et al., 2003). These may be potentiating situations because yips-affected golfers describe themselves as more anxious than unaffected golfers (Sachdev, 1992). Compared with their peers, yips-affected golfers showed higher mean heart rate and increased electromyogram activity in the wrist flexors and extensors, and they used more grip force before and throughout the putting stroke (Smith et al., 2000), which might be an indication of an increased level of arousal. Importantly, no differences were found in general grip strength, mental and motor speed, and visuomotor coordination (Sachdev, 1992), which suggests that the differences are task-specific and may be moderated by increased arousal during putting. The strong indication of the influence of psychological factors warrants its further investigation.

Although the potential influence of psychological factors has been acknowledged, little is known about the thoughts and feelings of yips-affected golfers. Moreover, to the best of our knowledge there is no information about their focus of attention even though attention is a crucial component of performance (e.g., Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007). For example, it has been shown that skilled athletes have worse outcomes when they focus on details of their own movement execution (i.e., self-focus or internal focus of attention) instead of adopting a more holistic internal focus (i.e., swing thought) or focusing externally away from skill execution (i.e., on the effect of the movement or a secondary task) (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Carr, MacMahon, & Starkes, 2002; Castaneda & Gray, 2007; Gucciardi & Dimmock, 2008; Wulf, 2007). The effect of an internal focus of attention on the performance outcome of novices, however, is less clear. Some studies have indicated that an internal focus on skill execution promotes performance outcomes in novices (Beilock et al., 2002, 2004; Castaneda & Gray, 2007). However, it has also been shown that an external focus on the effect of a movement (e.g., focusing on the head of a golf club) while learning a task leads to better outcomes and retention (e.g., Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007) or does not affect the outcome differently from an internal focus of attention (Poolton, Maxwell, Masters, & Raab, 2006).

In addition to the aforementioned findings, a broad body of research suggests that choking, which is thought to be the underlying mechanism of Type 2 yips, can be attributed to dysfunctional attentional foci (see Hill et al., 2010, for a review). For example, the execution of skilled movements can be disturbed by an attempt to monitor or consciously control one's own skilled movement (i.e., self-focus). Alternatively, the processing of task-irrelevant information (i.e., distracting thoughts) can lead to suboptimal processing of task-relevant information and might eventually result in choking. The assessment of focus of attention is thus relevant in order to identify possible performance-deteriorating attentional strategies in yips-affected golfers. This information might not only lead to a better understanding of the phenomenon of the yips, but might also provide a starting point for future interventions. Furthermore, given the suggestion that the yips is a task-specific focal dystonia (Type 1), understanding the role of focus of attention in the yips might also contribute to advances in other disciplines that are affected by focal dystonias (e.g., music). To the best of our knowledge, no study on the focus of attention in patients with a focal dystonia exists.

The limited research linking the yips phenomenon to focus of attention or to thoughts and feelings led us to seek a deeper understanding of these potential relationships. We chose a qualitative method to assess focus of attention, thoughts, and feelings of yips-affected golfers, because it allows for a rather unrestricted exploration of the potential relationships. Consequently, this method allows for a deeper understanding of the personal experience of the yips, which contributes to a better understanding of the phenomenon, such as underlying mechanisms and moderators. Additionally, qualitative investigations might also shed light on the long-term nature of yips (Bawden & Maynard, 2001). Bawden and Maynard (2001) conducted an interview study on the yips of bowlers in cricket and concluded that a feeling of entrapment due to the nature of the bowler's task might contribute to the perpetuation of the yips. Although bowling in cricket is a fundamentally different skill from putting, the study provides an excellent example of the usefulness of studying the thoughts, feelings, and behavior of yips-affected golfers. Our main aim was therefore to investigate the thoughts, feelings, and focus of attention of yips-affected golfers by means of semi-structured interviews.

2.3. METHOD

2.3.1. PARTICIPANTS

Participants were 17 golfers (5 women, 12 men) with an average age of 47.65 years (*SD* = 15.61). Their golfing experience ranged from 4 to 60 years (*M* = 20.82 years, *SD* = 16.42). The participants' handicap (hcp) ranged from 0 to 33 (*M* = 11.97, *SD* = 11.23, including three professional instructors with hcp = 0). All participants had tournament experience ranging from club level to national championship tournaments.

Yips-affected golfers in the present study were identified in accordance with the criteria of Smith et al. (2000). That is, participants were reported as experiencing abnormal putting movements in the hand or forearms either by self-description or by observation by teaching professionals. The abnormality was defined as a jerking, shaking, or freezing of the movement, occurring when putting with a regular putter and a conventional grip (nondominant hand on top). The symptoms prompted the golfers to seek a change in grip (n = 15) or equipment (n = 9).

A change in the grip typically involved a change from a regular grip to a cross-handed grip, which was effective for one participant. The remaining participants noticed some, albeit inconsistent, improvement. One participant reported that he switched the side from which he putted, thus using the unaffected hand to lead the putting movement. After that switch and learning to lead the putt with the nondominant hand, he no longer experienced the yips.

Typical changes of equipment were a new regular putter, a heavier putter, and a longer putter (i.e., broomstick putter). A heavier putter led to slight improvement, but the broomstick putter turned out to eliminate the yips symptoms completely in all participants who used it (n = 4).

All golfers were good putters before the onset of the symptoms or after finding a successful intervention (e.g., different grip or different putter). None of the participants reported having a problem with movement control other than the yips. Subsequent to the interviews three participants were excluded because they did not meet all inclusion criteria.

We did not exclude participants based on their golf handicap, which is an indication of their skill level, because the handicap heavily depends on the number of putts needed to finish a round of 18 holes and thus in the case of yips-affected golfers is often negatively biased. Additionally, we did not exclude golfers based on their golf experience. Although on average yips-affected golfers seem to have played golf longer than unaffected golfers (McDaniel et al., 1989) and repetitive training increases the likelihood of developing a focal dystonia (Jabusch & Altenmueller, 2006), there is no evidence that the yips only affects golfers with many years of experience. A more important inclusion criterion seems to be the task-specificity of the typical involuntary contractions. To gain a sounder understanding of the yips phenomenon, it is not only important to exclude potentially unaffected golfers but also to include the whole range of yips-affected golfers.

At the time of the interview, all participants were experiencing the yips while putting with a regular putter and regular grip. The duration of yips experience ranged from 6 months to 13 years with a mean duration of 4.74 (SD = 3.92) years. An overview of the individual demographics of all participants is depicted in Table 2.1. Additionally, Table 2.1. shows the individual yips characteristics such as duration of the yips, description of the yips movement, types of putts affected, frequency of the yips occurrence, and situations affecting the severity of the yips.

2.3.2. INSTRUMENT

We used a semi-structured interview approach to ensure standardized, open-ended, and nonsuggestive questions. The interview guidelines were developed by the authors in collaboration with a professional golf instructor. The interview consisted of two sections: (1) Section 1 focused on the thoughts and feelings associated with situations in which the yips occurs. First, participants were asked to describe (a) the abnormality they had experienced during a putting movement and (b) a typical situation in which they had experienced the yips. Second, they were asked to describe the feelings they had experienced in relation to this situation. Third, they were asked to report what they thought about in that situation. We did not specify whether these thoughts and feelings needed to be before, during, or after the specific yips experience; rather, we were interested in uncovering the most dominant feelings and thoughts that came to participants' minds when they described a typical yips situation. (2) The second section dealt with participants' focus of attention right before performing the yips-affected stroke (i.e., a putt). Participants were asked to describe what they focused on after they had addressed the ball and right before they performed the putt. It was mentioned that their focus might change and that we were interested in what they focused on most of the time.

The guidelines were tested twice in interviews with yips-affected golfers who were not part of the present study. The results were deemed sufficient for the purpose of the study and only minor corrections in phrasing were made. The study was approved by the ethics committee of the authors' university.

Table 2.1. - Participant's Demographic Data and Description of Their Yips Characteristics

P.	Age	Golf experience (handicap)	Duration of the yips in years	Participant's description of the yips	Putts affected by the yips	Frequency of the yips	Situations affecting the yips
1	59	8 years (25.6)	8	Waggling before impact	Short putts	Always	Most severe in tournaments
2	29	21 years (1.4)	2	Jerk before impact	All putts	Often	Most severe in tournaments
3	39	20 years (0)	1	Jerk before impact	Mostly short putts	Sometimes	Most severe in tournaments
4	40	22 years (4.3)	10	Jerk at transition from back to forward swing	Mostly short putts	Always	Most severe in tournaments
5	52	5 years (7)	0.5	Waggling already at takeaway	Mostly short putts	Often	Most severe in tournaments
6	55	10 years (22.1)	10	Jerk before impact	All putts	Always	All situations the same
7	30	17 years (31)	10	Shaking before impact	All putts	Often	Most severe in tournaments
8	44	15 years (0)	2	Jerk before impact	All putts	Often	Most severe in tournaments
9	26	4 years (33)	3.5	Jerk before impact	Mostly short putts	Always	All situations the same
10	58	23 years (10.2)	3	Jerk before impact	Only short putts	Often	Most severe in tournaments
11	71	60 years (4.1)	13	Jerk during forward swing	Only short putts	Often	Only in tournaments
12	66	29 years (22)	3	Jerk before impact	All putts	Always	All situations the same
13	68	59 years (8)	3	Jerk before impact	All putts	Often	Most severe in tournaments
14	41	29 years (2.7)	.5	Shaking during forward swing	All putts	Often	Most severe in tournaments
15	68	9 years (16.6)	2	Shaking before impact	Mostly short putts	Often	All situations the same
16	26	13 years (0)	4	Jerk before impact	Only short putts	Often	Only in tournaments
17	38	10 years (15.4)	5	Shaking already at the backswing	Mostly short putts	Often	All situations the same

Note. P. = participants. Due to the qualitative nature of the data collection, the frequency of the yips could only be categorized on an ordinal level. *Sometimes* refers to the experience of the yips on less than 50% of all putts, whereas *often* refers to the experience of the yips on more than 50% of all putts.

2.3.3. PROCEDURE

The participants were contacted directly by their professional golf instructor or by email via the newsletter of their golf club. We posted the information that we were looking for participants who had noticed an abnormality in their putting movement or were having difficulties putting that would not improve despite increased training efforts. Some of the participants were contacted directly by the professional golf instructor who helped design the study or by the interviewer. Participants were not paid for their participation. The term yips was not used until the participants mentioned it themselves. Unless participants called their putting problem yips we kept referring to it as the abnormality in the putting movement that they were experiencing.

Only one interviewer, who was trained in conducting interviews and was familiarized with the interview guidelines, conducted all the interviews. Moreover, the interviewer is a highly experienced golfer and thus familiar with the sport-specific terms and reported situations. The interviewer met with the participants in a quiet place in their home or at their golf club. The participants were informed about the goal of the interview and asked whether they would allow an audio recording. They signed an informed consent document assuring them that their data would be treated confidentially and anonymously and confirming that their participation was voluntary. The participants received the contact details of the interviewer in case of any questions or additions that they might think of after the interview.

2.3.4. DATA PREPARATION AND ANALYSIS

All interviews were transcribed verbatim. Two researchers (first author and interviewer) independently listened to the recordings and carefully re-read the transcripts to become familiar with the content. Following this familiarization, the transcripts were analyzed using Mayring's (2000) approach to qualitative content analysis, which is based on earlier developments of content analysis (e.g., Krippendorf, 1980). The method is very similar to approaches successfully used in sport psychology studies (e.g., Bawden & Maynard, 2001) with a strong additional focus on the emergence of categories.

Following this approach, categories were built inductively and deductively. Deductively derived categories followed the sections of the semi-structured interview guidelines. Inductively derived categories were developed using the procedure described by Mayring (2000). That is, the general focus of the study constrained the focus of the two researchers to the relevant topics. Within this framework the transcripts were read successively and salient quotes were listed. Subsequently, similar quotes were clustered and meaningful superordinate categories (so-called lower order themes, LOTs) were built. This procedure allows LOTs to emerge from the raw data. After all relevant data were categorized into corresponding LOTs, categories were built that clustered multiple LOTs into meaningful higher order themes, if appropriate.

To ensure the reliability of the analysis, the first author and the interviewer independently categorized the raw data. After initial coding, the raters agreed on 89% of the raw data. After discussing the discrepant items, the raters agreed on all items. The second author, who is experienced in qualitative research (Lobinger & Solomon, 2010), supervised the preparation, execution, and analysis phase of the interviews. To verify the results of the content analysis, the interview of each participant was summarized according to the categories that emerged. The summaries were mailed to the participants with the request to check whether the summaries truly reflected their answers. All participants confirmed the results.

2.4. RESULTS

The following section presents an overview of the results. To give the reader an impression of how participants experience the yips, exemplary quotes are presented. For the sake of readability, grammatical mistakes were corrected.

2.4.1. SECTION 1—THOUGHTS AND FEELINGS ACCOMPANYING THE YIPS-AFFECTED STROKES

Participants were asked to describe the thoughts and feelings they usually experienced in a yips situation. Specifically, participants were initially asked to describe their yips and the situations in which the yips occurred. Next, they were asked to describe what they had felt during that situation, followed by what they had thought about in that situation. Figure 1 depicts the detailed categorization of the participants’ reports. The picture that emerged from the categorization is that participants reported clearly negative thoughts and feelings associated with the yips and the situations in which it occurs. It should be noted that while it is sometimes difficult to clearly distinguish between feelings and thoughts, for the sake of clarity, the following results are presented separately for each construct.

2.4.1.1. Feelings of golfers in yips situations.

Fear of putting was the most frequently reported negative feeling, with seven participants explicitly reporting having developed a fear of putting because they were afraid that the yips would occur again. For example, one participant (P) said, “I am shaking; it is fear of putting; it is fear. When I need to take a short putt I am afraid that I will miss again” (P1). Another participant reported, “I think it is some kind of unconscious fear when putting. I only have this [fear] with putting. With all the other strokes it is no problem at all. It is somehow, it is so deep, the fear that I will miss the putt again.… It is unconscious; I already experience some sort of fear or something like that. I do not have another explanation for something like this [yips]” (P4). Again another golfer answered: “Yes, I feel downright fear. Especially on short putts. After all these years of playing golf I should expect from myself to hole the ball without looking, but I am glad even when I just hole 1 out of 4 putts from about 1 meter away” (P15). The three quotes are representative of the responses given by the seven participants whose answers showed that they were experiencing a fear of having to take a putt, because they were afraid that the yips would occur again and they would, therefore, miss the hole again. Some participants felt the fear only when they had to take a putt from a distance at which they often or always experience the yips. Still other golfers’ reports showed that the fear was already building up when they were approaching the green: “As I get closer and closer to the flag, I think, ‘oh my god, I am going to have to putt again,’ and it certainly gives me a headache” (P9).

Anger was the second most often mentioned feeling with five participants reporting feeling angry about their problem with the yips. One golfer, for example, acknowledged that it is normal to miss an easy putt once in a while, but the sum of the missed putts created his anger, “As I said, everyone can miss a putt once in a while, but when you miss a number of putts on one round, then you really get angry” (P7). Another golfer expressed his anger about the yips with the following words, “Yes, of course you were angry. No doubt. Actually you play well, you play straight balls and then you cannot putt the ball in. Of course you get angry then” (P6). The answers show that one emotional consequence of the yips is to feel angry about unsuccessful putting, possibly because it prevents them from reaching a better result.

The inability to control the yips and, thus, the putting movement also led to feelings of disappointment and frustration, as exemplified by the following: “All I can really say over and over again is ‘inner disappointment.’ Disappointment, because you played the last 4 hours in vain. The goal is to reduce your handicap and while the rest of the game goes well, you do not achieve your goal because of the putting. Then you are disappointed that you did not get it under control” (P11). Another golfer described his emotional experience of the yips as “pure horror”: “Terrible. If you, let’s say, as a talent or as an athlete, cannot hole a putt from half a meter away, which every grandpa or grandma could do, then this is hard to describe in words. Thus, a competence that accompanied you all your athletic life is gone all of a sudden.… It [the feeling] ranges between frustration, resignation, disappointment, anger. Well, it is the whole range of emotions from A to Z” (P8). It is evident from these quotes what kind of emotional burden the yips can pose for an affected athlete.

Another negative feeling that was reported by the participants was a feeling of helplessness. One participant answered, “Completely helpless. There really is a feeling of helplessness when you are putting during a round of golf. You actually play a good round and then the putting does not work in the end. There is nothing you can do about it” (P4). Yet another golfer described the yips as a physical inability to control the movement, “It is just this uncontrollable shaking and cramping. You almost feel like you are physically not capable of controlling your body at that moment” (P7). The reports of feeling helpless indicate that some golfers experience a lack of control over their putting movement.

2.4.1.2. Thoughts of golfers when experiencing the yips.

The thoughts that were reported by the golfers were categorized as worries about mistakes or the yips, loss of confidence in their putting skill, and thoughts about the outcome. Worries about mistakes were reflected by seven participants who reported that they (a) hoped not to have the yips again when they needed to putt, (b) worried about not being able to hole a putt, or (c) had thoughts about their previous mistakes. As one participant described it, “No, the thought that I want to hole the ball is only there very few times. It is more often the thought ‘please not three putts again’” (P10). Another golfer said, “Of course there is a sort of tension, always with the thought ‘just do not miss it again.’ That means I do have the positive thought that the ball needs to go in, which I try to talk myself into, but eventually, in the back of my head, the thought not to miss the hole again is stronger. Thus, there is always the negative thought, but unfortunately I cannot avoid it" (P11). Another participant answered the questions about his thoughts in a yips situation with the following words: "I am thinking 'please do not screw it up again.' Well, it is because of the problem that I already expect a bad putt" (P15).

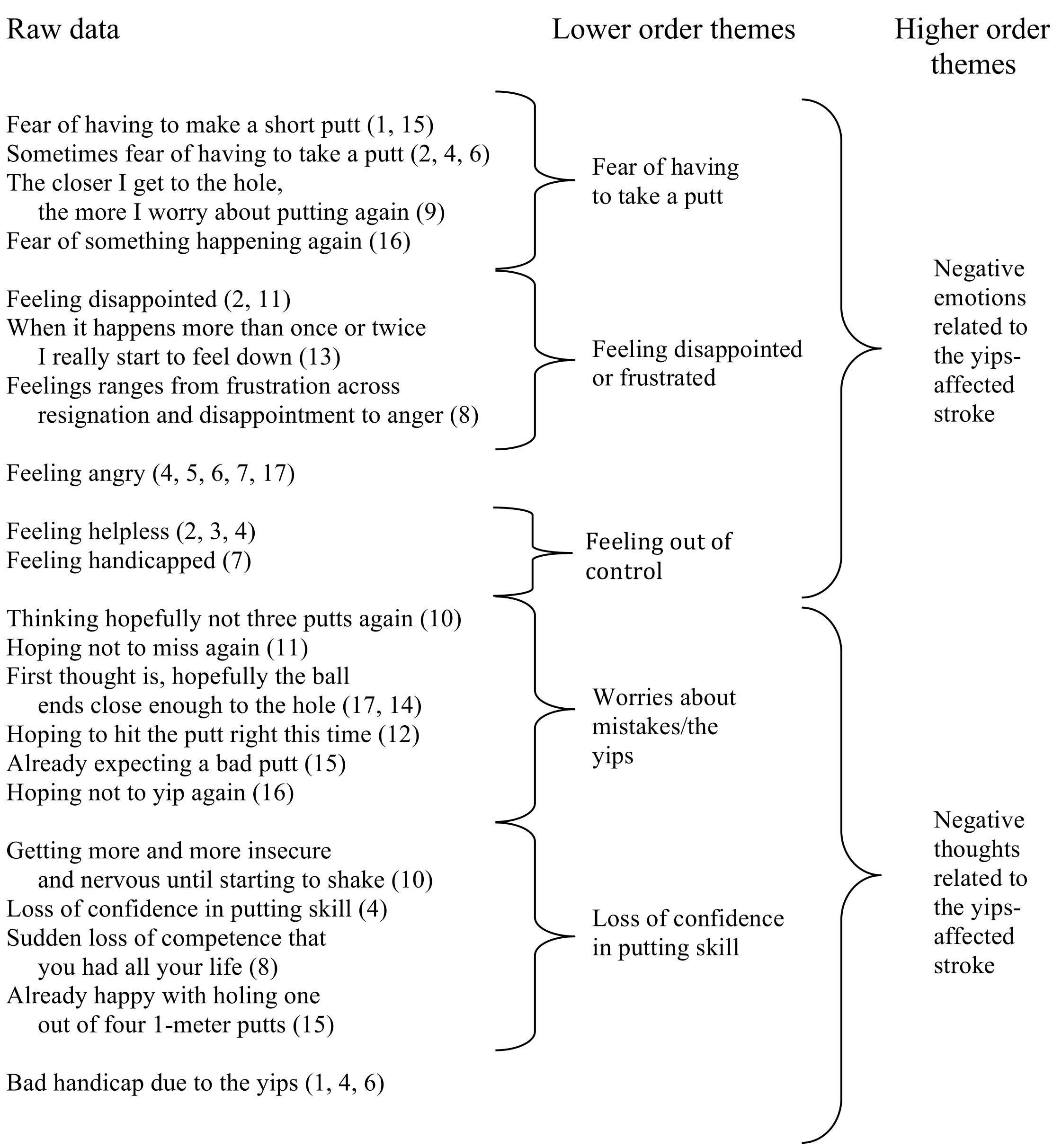

Figure 2.1. - Categorization of personal experience with the yips. Numbers in brackets are the participants' numbers and correspond to the references in the text and the participants' numbers in Table 2.1.

Loss of confidence in the putting skill was expressed in the answers of four participants. For instance, one golfer explicitly said, “It is such a catastrophe, putting with the yips. I have absolutely no confidence in my putting game. It is terrible” (P4). Furthermore, the participants stated that they felt insecure when needing to putt or reduced their expectations of the results on the putting green, as illustrated by this participant’s statement: “I am already happy when I hole one putt out of four 1-meter putts” (P15).

Thoughts about the outcome are illustrated by the following quote: “And then I also think that [pause] every time, my handicap is so high because I putt so badly.… Because I could have a whole different handicap if my balls would go in the hole” (P1). Two more golfers explicitly mentioned thinking about how the yips is responsible for their handicap, which they were sure would be better if they were only capable of putting more successfully.

2.4.2. SECTION 2—FOCUS OF ATTENTION DURING YIPS-AFFECTED STROKES

To provide insight into the participants’ attentional focus while putting, the participants were asked to describe what they focused on after they addressed the ball, right before they performed the putt. The answers of 15 participants were categorized into LOTs: focus on technical aspects, focus on the yips and negative outcomes, and focus on the goal or effect of the movement. Figure 2 depicts the detailed categorization of the participants’ reports.

A focus on technical aspects was reflected in the answers of seven participants. They focused, for example, on a controlled takeaway, “It [the focus] is always on the slow takeaway … only on the takeaway” (P13); on a controlled forward stroke through the ball, “I must focus on keeping my head down and then on really guiding the club forward so that it has a chance” (P17); or on a number of technical aspects, “I think about the course of movement. I focus on the takeaway and the grip but think about that before, and then actually in the last moment I tell myself ‘now you swing smoothly through the ball’” (P6).

A focus on the yips and the negative outcome right before putting was reported by four participants. For example, one participant reported hoping not to putt the ball too far away from the hole: “The focus is simply on thinking, ‘not too far away from the hole.’ The whole misery is that anything can happen. I know I suffer from this phenomenon, so I think, ‘please do not putt the ball too far away from the hole so that I have at least a chance to hole the ball with the second putt’” (15). Two other golfers said that they thought about the yips and hoped it would not happen again. For example, one participant said, “Well, while putting, because I know that I do not have everything under control, it is true that I sometimes have the wrong mental attitude. I think, ‘hopefully [my hand] is not shaking again’ and then I look at my hand and then it is already shaking, of course” (P5).

Raw data	Lower order themes
Improving technical mistakes of previous stroke (1) First about takeaway and grip, then about a smooth movement (6) Focus on the takeaway, trying to keep it stable (11) Thinking about alignment, takeaway, and follow-through the ball (12) Focus on keeping takeaway slow (13) Focus on technical changes (14) Keep head down and follow through the ball (17)	Focus on technical aspects
Thinking about the yips and hoping it does not happen again (5, 8) Thinking about the yips, hoping the putting is not going to be too bad (10) Focusing on the yips, hoping the ball does not end too far away from the hole (15)	Focus on the yips or the negative outcome
Visualization of goal (3, 16) Focus on the direction of the putt and the line to the hole (7) Thinking of holing the put (4)	Focus on goal or effect of movement
Taking the least number of shots possible (9) Various things, such as pressure on thumbs or a song (2)	Miscellaneous

Figure 2.2. - Categorization of the focus of attention while putting. Numbers in brackets are the participants’ numbers and corresponds to the references in the text and the participants’ numbers in Table 2.1.

A focus on the goal or the effect of the movement was described by four participants. One golfer said he only visualized the hole (P3). Another golfer only focused on the “ball and the hole or something else, but never on the movement…,” because that would disturb her performance completely (P16). The other two golfers said that there was no special thought, rather a focus on the direction of the putt (P7), or thoughts about holing the ball (P4).

Of the two participants whose answers were not categorized, one reported that he only thought about taking the least number of shots possible (P9). The other reported having various thoughts throughout the season that ranged from thoughts about pressure on the thumb to a song that he had heard (P2).

2.5. Discussion

The main aim of the present study was to investigate the thoughts, feelings, and focus of attention of yips-affected golfers. From the interviews it becomes apparent that yips-affected golfers have a negative (i.e., dysfunctional) cognitive and emotional association with the task of putting (i.e., a yips-affected stroke). The results show that the golfers were predominantly occupied with negative thoughts such as perceived loss of control, loss of confidence in their putting skills, and worries about mistakes due to the yips. In addition, the feelings associated with the yips were exclusively negative, including disappointment, frustration, anger, and especially anxiety about having to take a putt. The results are in line with previous studies on the yips. Bawden and Maynard (2001) reported that bowlers in cricket who experienced the yips described feelings of anxiety, perceptions of no control, a preoccupation with negative thoughts, and negative emotions. The results of the present study also indicate that the negative thoughts and feelings associated with the putting game and the yips, respectively, are subjectively experienced rather intensely. However, although most authors acknowledge an aggravating effect of anxiety on the symptoms of the yips, it seems that yips-affected golfers do not differ from the norm in their levels of anxiety (McDaniel et al., 1989; Sachdev, 1992). A possible explanation for these equivocal findings might be that it is not solely the intensity of anxiety that aggravates the yips symptoms, but rather the way the golfers cope with it. Vickers and Williams (2007) showed that high cognitive anxiety and physical arousal do not necessarily lead to choking in all athletes. And Hill et al. (2010) pointed out that the relationship between cognitive anxiety, physical arousal, and performance might be influenced by variables such as self-confidence and perceived control. How these factors influence the yips symptoms, however, is not yet clear.

In addition to exhibiting the negative cognitive and emotional pattern, 11 of the 17 participants reported a focus on technical aspects or a focus on the yips and its negative performance outcomes. According to the literature on attention in sports (e.g., Abernethy et al., 2007; Beilock et al., 2002, 2004; Castaneda & Gray, 2007) and choking (e.g., Beilock & Gray, 2007; Hill et al., 2010), a focus on possible mistakes or technical aspects of the movement often results in a suboptimal performance of a skilled movement. However, for novice performers, who have not automated skill execution to a high degree, the focus on the movement itself does not necessarily harm its execution (e.g., Beilock et al., 2002, 2004; Poolton et al., 2006).

The question for the present study is thus to what extent the putting movement is or was automated in the participants. The golfers' experience and handicap give some indication about the skill level of the participants and show that the majority of the participants had many years of experience and a considerably low handicap. There were, however, a few participants who did not have extensive golf experience and it is thus not clear how skilled they were in putting. The focus of attention might thus have a different effect on their performance as compared with the more skilled golfers.

The present study obviously does not allow conclusions regarding the underlying mechanisms of the yips. The negative cognitive and emotional pattern as well as the maladaptive attentional focus might simply be a consequence of the inability to perform a smooth putting stroke. However, the effect of these psychological factors on the yips might be crucial, as a study by Bell, Skinner, and Fisher (2009) indicated. The authors showed that an intervention based on imagery, which guides the golfer to focus on the thoughts and feelings prior to the onset of the yips, cured the visible symptoms of the yips in three golfers. Furthermore, the fact that certain psychological factors distinguish good golfers from better golfers is known (Bois, Sarrazin, Southon, & Boiché, 2009). To what extent these factors distinguish yips-affected golfers from non-affected golfers, however, remains unclear.

Assuming that psychological factors have an influence on the yips, the negative experience of the yips might offer an explanation for its long-term nature. It is possible the yips endures as a result of entrapment in a cycle of negative expectations and experiences about one's putting skill or perceived control of the movement. As is the task of bowling in cricket, putting[1] might be experienced as a continuously threatening process, as it cannot be avoided and needs to be finished "successfully" (Bawden & Maynard, 2001). Although we did not apply any psychometric measures it seems plausible to assume that a situation described as fear inducing (i.e., having to take a putt) is perceived as a high-pressure situation. Thus, yips-affected golfers might continue to experience the yips because the perception of pressure due to the demands of the putting task is regularly reinforced by negative feedback about the outcome. However, this explains neither why the yips occurs in the first place nor the underlying mechanisms responsible for the debilitated movement execution.

To allow conclusions about the influence of psychological factors such as anxiety or the focus of attention on the yips, one could design an intervention study to investigate whether a change in the emotional state and/or the focus of attention leads to a change in the symptoms of the yips. For future studies we also recommend developing a diagnosis that allows a reliable distinction between the yips and simply bad putting and optimally quantifies the yips. Additionally, it will be important to develop a method that can distinguish between the potential subtypes of yips. A good example of such an attempt is the study by Stinear et al. (2006). Given the current postulation of multiple causes of the yips in the literature, it is likely that Type 1 yips and Type 2 yips will be affected differently by the same intervention.

The present study assessed thoughts, emotions, and focus of attention of yips-affected golfers and thus provides a possible starting point for the development and evaluation of interventions for the yips. It does not, however, distinguish between the potentially different types of yips that have been proposed in the literature (Smith et al., 2003; Stinear et al., 2006). Additionally, as with all qualitative and retrospective studies, it needs to be pointed out that the participants' answers might be biased or distorted by false memory. Moreover, although thoughts, emotions, and focus of attention have been treated as separate categories in the present study, it is obvious that there is always an overlap between thoughts and emotions in qualitative reports about one's personal experience. Furthermore, it is virtually impossible to clearly distinguish the focus of attention from thoughts right before or during putting. Yet, in

[1] Putting is different from all other shots in golf, because they have a higher error tolerance due to the possibility of compensating with the next shot, whereas a missed putt always adds an extra stroke to your scorecard.

spite of the methodological limitations, the present categorization serves well to promote a better understanding of how golfers experience the yips and which processes might be involved in the yips and its long-term nature. This provides practitioners with valuable information to develop effective treatment.

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3. CHAPTER – PREVALENCE OF THE YIPS IN GOLF ACROSS THE ENTIRE SKILL RANGE

This chapter is based on:

Philippen, P. B., Klämpfl, M. K., & Lobinger, B. H. (under review). Prevalence of the yips in golf across the entire skill range. *Human Movement Science*.

3.1. Abstract

The yips are considered a form of task-specific focal dystonia (TSFD). Its estimated prevalence, however, is high compared to other TSFDs, possibly resulting from previous studies' sample restrictions based on skill level. Alternatively, this high prevalence might be an indication of additional etiologies. Thus, we estimated the prevalence of golfers at all performance levels. We additionally examined the relationship between yips and golfers' sports biographies as a potential risk factor.

Two online surveys examined prevalence of the yips and golfers' sports biographies.

Across the entire skill range, 22.4% of the golfers reported being currently affected by yips. Furthermore, more yips-affected than unaffected golfers had played a sport that requires the interception of a ball with an object that is controlled with the hands. The yips prevalence remains higher than that of other FDs. Previously played sports might be related to the onset of yips in golf.

3.2. INTRODUCTION

The most common type of late-onset primary dystonia is task-specific focal dystonia (TSFD; Fahn, Marsden, & Calne, 1987; Stinear, Coxon, & Byblow, 2009). TSFDs have been observed in various contexts (Byl, 2006; Jabusch & Altenmueller, 2006), including in a range of sports (Adler et al., 2011; Bawden & Maynard, 2001; Le Floch et al., 2010; Mayer, Topka, Boose, Horstmann, & Dickhuth, 1999), with golf and the yips (Adler, Crews, Hentz, Smith, & Caviness, 2005; Bell, Skinner, & Fisher, 2009; McDaniel, Cummings, & Shain, 1989; Sachdev, 1992; Smith et al., 2000; Stinear et al., 2006) being a primary focus of research. The yips is an involuntary jerking and twisting of the forearm, usually while putting (Adler et al., 2011; Smith et al., 2003).

The etiology of the yips is unclear. Neurophysiological reasons for the yips have been postulated based on its task-specificity, its physical manifestation, and observed cocontractions (Adler et al., 2005; Adler et al., 2011; McDaniel et al., 1989; Sachdev, 1992). Psychological reasons have been suggested based on the symptoms worsening under stress (Masters & Maxwell, 2008). A neurophysiological–psychological interaction has also received some support (Adler et al., 2005; Smith et al., 2000, 2003; Stinear et al., 2006). It is possible that different underlying mechanisms manifest in the same physical symptoms. For instance, it was shown that two prototypical TSFDs (writer's cramp and musician's cramp) have different etiologies (Rosenkranz et al., 2005). An indication for other reasons of the yips besides TSFD is the high prevalence among golfers compared to the general population or other specific disciplines, such as music.

The prevalence rates of TSFDs in the general population is estimated between 0.01% and 0.03% (Fukuda, Kusumi, & Nakashima, 2006; Nutt, Muenter, Aronson, Kurland, & Melton, 1988) and in the specific population of musicians at about 1% (Altenmueller, 2003). In comparison, the yips prevalence rates seem to be 30 to 5,000 times higher (McDaniel et al., 1989; Smith et al., 2000). The large discrepancy in prevalence might be a consequence of the aforementioned multiple etiologies and/or the limitations of the previous yips prevalence studies. These studies focused exclusively on professional or highly competitive golfers and neglected the majority of the golfer population playing on a lower skill level (McDaniel et al., 1989; Smith et al., 2000). To investigate whether this prevalence discrepancy between the specific population of golfers and other groups affected by TSFDs is grounded in previous restrictions to skill and experience we need to compare previous prevalence estimations of the yips with prevalence estimations across the entire skill range. Thus, to get a better idea of how prevalent the yips is among golfers, we conducted an online survey addressing the entire skill range of golfers in Germany.

The second focus of the study was to explore alternative explanations for the large discrepancy in prevalence between the yips and other TSFDs, which might be an indication of alternative underlying mechanisms. Based on unpublished results of an interview study, it appears that yips-affected golfers often played racket sports before they took up golf (Philippen & Lobinger, 2012). Sometimes yips-like symptoms also occurred in these sports either before or after onset of the yips in golf. The individual sports biography might have an influence on the development of the yips. We therefore conducted a follow-up survey, investigating the sports biographies of yips-affected and unaffected golfers.

3.3. METHOD

3.3.1. YIPS PREVALENCE

3.3.1.1. Participants.

The sample consisted of 277 women and 1029 men. Demographics are listed in Table 3.1. The link to the survey was opened 4601 times and completed by 1366 participants. We excluded 60 participants from the sample based on the following criteria: (i) self-rated seriousness in answering the questionnaire was below 5 on a 9-point Likert scale ranging from 1 (*absolutely not serious*) to 9 (*absolutely serious*) (n = 31); (ii) age was younger than 18 (n = 13); (iii) golf handicap was higher than the possible maximum of 54 (n = 6); (iv) duration of playing golf in years was the same as or longer than age in years (n = 4); (v) onset of the yips was before beginning to play golf (n = 6).

3.3.1.2. Materials and procedure.

The participants signed the informed consent and were asked to rate on a 9-point Likert scale how seriously they were going to answer the questionnaire. The seriousness check is according to Reips (2002) standard for internet based research and increases the seriousness and completeness of participants' answers.

Subsequently, demographic data were recorded and the option to insert an e-mail address was given in order to receive further related questions. Next, a definition of the yips and its potential physical manifestations (Smith et al., 2003) were presented. Participants were asked if they had ever experienced the yips while golfing

Table 3.1. - Demographic Data of Yips-Affected and Unaffected Golfers and Comparison With Previous Yips Prevalence Studies

	McDaniel et al., 1989[12]	Smith et al., 2000[10]	Present study	
Recruitment (*n*)	Mailed to 1,050 golfers	Mailed to 2,630 golfers with hcp < 12	Link spread online in sport-specific forums, news magazines, and university homepage	
Response rate (*n*)	42% (441)	39% (1,031)	28.4% (1,306)	
Eligibility	PGA and USGA male golfers	Great golfing experience Male hcp < 10 Female hcp < 12	Subsample Male hcp < 10 Female hcp < 12	Entire skill range (hcp = 0–54)
Percentage (*n*) yips affected	28% (93)	53.5% (453)	45.2% (94)	22.4% (292)
Age in years (*SD*)				
Affected	50.5	45.2	41.15 (14.12)	49.2 (14.2)*
Unaffected	47.5	47.4	37.12 (11.88)	45.3 (13.7)
Hcp (*SD*)				
Affected	n.a.	4.45	5.46 (3.37)	16.7 (11.1)*
Unaffected	n.a.	4.53	5.64 (3.78)	28.0 (15.8)
Golf experience in years (*SD*)				
Affected	35.6	30.4	17.65 (9.68)*	12.0 (9.0)*
Unaffected	31.0	30.8	12.75 (8.81)	6.5 (6.7)

Note. PGA, Professional Golfers' Association; USGA, United States Golf Association; hcp = handicap; * = significantly different from unaffected golfers at $p < .016$.

and if so, if they were currently still affected by the yips. Possible answers were "yes", "no", or "I do not know" and triggered the next page of the questionnaire. If participants were currently still affected by the yips, they were asked about its physical manifestation, the affected body part, the affected side of the body, the affected stroke, and the affected situation. Additionally, they were asked if any other movements were affected by yips-like symptoms. If participants were not currently affected anymore or did not know if they still were, or if they never experienced the yips, then they were thanked for the participation and not asked any further questions.

The link to the questionnaire was spread via sport-specific forums, news magazines, and the homepage of the authors' universities. Only one participation per Internet protocol address was possible.

3.3.2. SPORTS BIOGRAPHY

3.3.2.1. Participants.

The follow-up survey was completed by 246 participants (46 women). Participants' mean age was 43.58 (SD = 16.4) years. The mean golf handicap was 19.34 (SD = 14.04) strokes and participants' mean golf experience was 10.00 (SD = 8.01) years.

3.3.2.2. Materials and procedure.

The follow-up questionnaire was e-mailed to all participants who voluntarily reported their e-mail address in the first questionnaire (N = 407). The questionnaire consisted of the informed consent and open questions about which sports besides golf participants had played and for how long.

3.4. RESULTS

3.4.1. YIPS PREVALENCE

The results show that 292 (22.4%) participants were currently affected by the yips, while 92 (7%) participants were no longer affected or were not sure if they still were. Moreover, 764 (58.4%) participants had never experienced the yips and 158 (12.1%) participants were not sure. Only the currently affected group (n = 292) and the never-affected group (n = 764) were included in further analysis in order to exclude unclear self-diagnoses.

The distribution of currently affected golfers in relation to never-affected golfers across the complete handicap range is depicted in Figure 3.1. The handicap median for the currently affected group was 15 with a range of 0 to 54, showing that the yips affects golfers across the whole skill range. Bonferroni corrected t-tests revealed that the never-affected group was younger, $t(1054) = 4.1$, $p = .000$, $d = 0.28$, had a higher handicap, $t(1054) = 11.22$, $p = .000$, $d = 0.83$, and had less golf experience, $t(1054) = 10.71$, $p = 0.000$, $d = 0.69$, than the currently affected group.

To allow comparison with previous prevalence studies, we excluded men with a handicap higher than 10 and women with a handicap higher than 12 (Smith et al., 2000). The subsample resulted in 33 women and 175 men with a yips prevalence of 45.2% (n = 94). Bonferroni corrected t-tests revealed that the never-affected group had less golf experience, $t(206) = 3.82$, $p = .000$, $d = 0.53$, but did not differ from the currently affected group in age, $t(206) = 2.23$, $p = .027$, $d = 0.31$, or handicap, $t(206) = .37$, $p = .716$, $d = 0.05$.

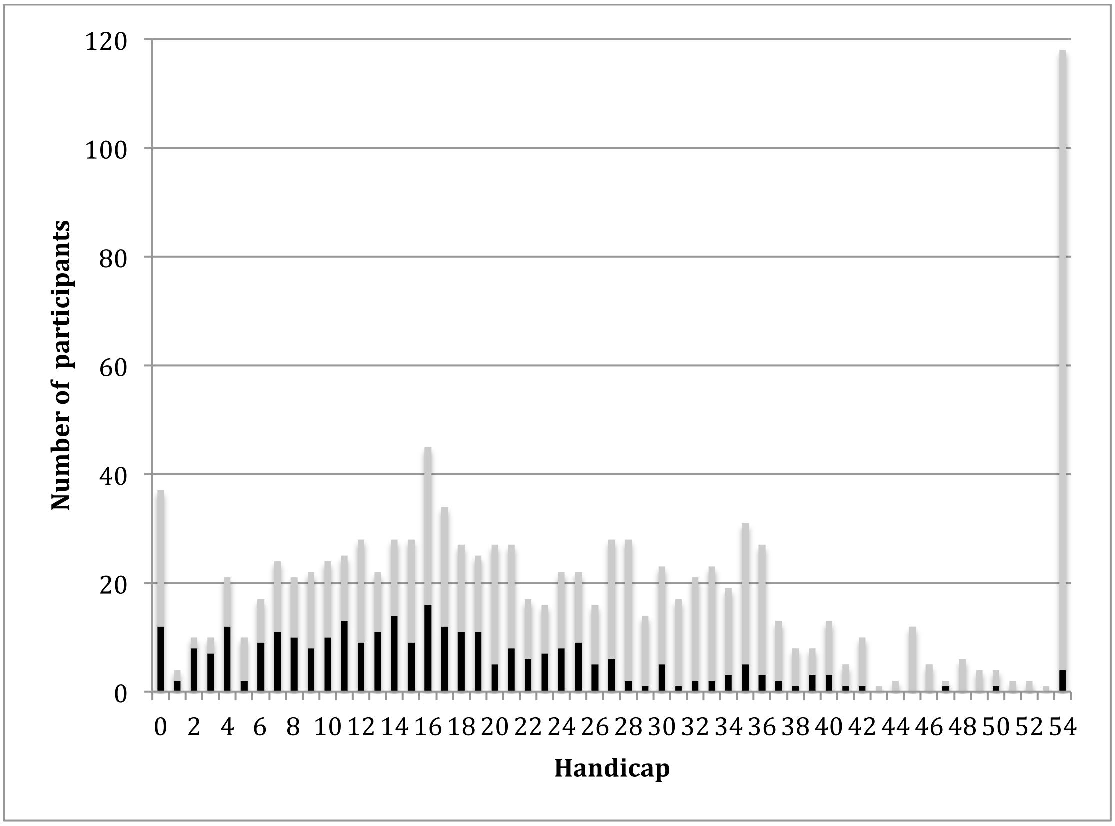

Figure 3.1. - Distribution of golfers from the sample population who had never experienced the yips (gray bars) and who were currently affected by the yips (black bars) across the entire handicap range.

The characteristics of the yips and the movements that are affected by yips-like symptoms, both based on the reports from the currently-affected group, are listed in Table 3.2. The results show that the yips occur most often in stressful situations while putting and manifest in a jerking, twitching, or cramping of the hand and/or forearm. The reports about other yips-like affected movements reveal that 20.4 % of the currently yips-affected participants also experience similar symptoms at other tasks. Noteworthy is that 50 % of these participants experience the yips-like symptoms while playing tennis, table tennis, or badminton.

Table 3.2. - Characteristics of The Yips and Tasks Other Than Golf That are Affected by Yips-Like Symptoms

Yips Characteristics	n of currently affected group
Situation first onset yips	
Tournament	122 (41.5%)
Stressful situation	84 (28.6%)
Practice round	48 (16.3%)
Practice area	34 (11.6%)
Other than that	6 (2.0%)
Physical manifestation	
Jerking or twitching of muscles	159 (54.1%)
Cramping of muscles	69 (23.5%)
Waggling of arm	67 (22.8%)
Shaking of muscles	39 (13.3%)
Freezing of movement	31 (10.5%)
Other than that	22 (7.5%)
Affected stroke	
Putts	249 (84.7%)
Short game (e.g., chipping)	60 (20.4%)
Long game (e.g., driving)	37 (12.6%)
Affected body parts	
Hand	187 (63.6%)
Forearm	176 (59.9%)
Upper arm	30 (10.2%)
Shoulder	27 (9.2%)
Leg	10 (3.4%)
Other than that	3 (1.0%)
Affected side of the body	
Right	191 (65.4%)
Left	56 (19.2%)
Both sides	45 (15.4%)
Affected Situations	
Tournament	186 (63.3%)
Stressful situation	184 (62.6%)
Practice round	117 (39.8%)
Practice area	78 (26.5%)
Other than that	5 (1.7%)
Other affected movements	
Tennis	23 (7.8%)
Writing	6 (2%)
Table Tennis	5 (1.7%)
Drinking from a full cup	5 (1.7%)
Billiard	4 (1.4%)
Badminton	2 (0.7%)
Miniature Golf	2 (0.7%)
Soccer	2 (0.7%)
Baseball	1 (0.3%)
Beachball	1 (0.3%)
Javelin	1 (0.3%)
Shooting	1 (0.3%)
Clink glasses	1 (0.3%)
Pointing with hand	1 (0.3%)
Computer mouse	1 (0.3%)
Writing on keyboard	1 (0.3%)
Other than that	3 (1.0%)
Total	60 (20.4%)

3.4.2. SPORTS BIOGRAPHY

Participants' answers were split into two groups. Group A included all participants who reported having played sports that involve the interception of a ball with an object that is held with the hands (e.g., rackets, sticks, or bats). Group B included all other participants. To test if there is a relation between sports history and the yips, Group A and Group B were further split into yips and no-yips groups. The categorization revealed the following distribution: Group A yips = 116; Group A no-yips = 72; Group B yips = 26; Group B no-yips = 32. A 2 (yips, no yips) × 2 (Group A, Group B) chi-squared test revealed that there is a relationship between being affected by the yips and having played a sport that requires the interception of a ball with an object that is controlled with the hands, $\chi^2(1) = 5.172$, $p = 0.023$, $\theta = 0.14$.

3.5. DISCUSSION

The present study is the first to estimate the prevalence of the yips in Germany across the entire skill range. The results show that high-handicap golfers with relatively little experience also report being affected by the yips. This seems contradictory to the postulation that all forms of the yips are a TSFD (McDaniel et al., 1989; Sachdev, 1992). The prevalence of the yips across the entire skill range can be estimated at around 22.4%. This range is below the previously reported prevalence rates of 53.5% (Smith et al., 2000) and 28% (McDaniel et al., 1989). When only considering the subsample of highly skilled golfers the prevalence estimation increases to 45.2%, approximating previous estimations based on a similar subsample (Smith et al., 2000). This indicates that the prevalence of previous estimations might have been inflated by the limitation to highly skilled golfers. However, even when including the entire skill range the prevalence estimations of yips are relatively high compared to other TSFDs (e.g., Altenmueller, 2003).

Possible explanations for the higher yips rates compared to other TSFDs include false reports by novices, multiple reasons underlying the yips symptoms, or overtraining of the affected muscles resulting from previously played sports. The latter explanation is tentatively supported by the results of the follow-up questionnaire, showing that significantly more yips-affected than unaffected golfers had played a sport that, like golf, requires a coordinated hand–eye movement to intercept a ball with an object.

Two mechanisms for developing the yips are conceivable. First, playing racket sports, such as tennis or badminton, may result in a kind of overuse of one hand or arm, which triggers the onset of the yips in golf in the form of a TSFD. Previous understanding was grounded in the belief that TSFD is caused by extensive repetitions in one specific task (Altenmueller & Jabusch, 2009). Second, the yips could be the consequence of a negative transfer or proactive interference describing the negative effect of a previously learned skill—for example, a tennis forehand swing—on a new skill—for example, a golf putt (Rose & Christina, 2006). This approach is based on the theory of sensorimotor learning, which deals with the interaction between sensorimotor feedback and the motor memory during the acquisition of a motor skill. It also includes the concept of structural constraint saying that with an increase of practice, tasks become structurally more constrained and the execution gets more and more task-specific. Motor skills get consequently less adaptive and can only be partially transferred on not yet learned skills, especially if implicit representations have been developed in the motor memory. In this context, the influence of the similarity of the skills, the amount of practice of the skills, and the delay between the practice of the two skills have been controversially discussed (Tallet, Kostrubiec, & Zanone, 2004). For future studies it would be interesting to investigate the relation of these factors with the onset of the yips in golf.

To summarize, the prevalence of the yips still seems overly high compared to other TSFDs. In our study novices also reported suffering from the yips, and yips-affected golfers more often than unaffected golfers reported playing a racket sport. These findings may indicate new, previously overlooked mechanisms. Further research in this direction is strongly encouraged to increase our understanding of both the yips in sports and TSFDs in general.

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4. CHAPTER – DIAGNOSING AND MEASURING THE YIPS IN GOLF PUTTING: A KINEMATIC DESCRIPTION OF THE INVOLUNTARY MOVEMENT COMPONENT THAT IS THE YIPS

This chapter is based on:

Philippen, P. B., Legler, A., Land, W. M., Schuetz, C., & Schack, T. (under review). Diagnosing and measuring the yips in golf putting: A kinematic description of the involuntary movement component that is the yips. *Sport, Exercise, and Performance Psychology*.

4.1. ABSTRACT

The yips is an involuntary movement disrupting the smooth motion of the golf putting stroke. The study's aim was to provide an objective measurement of the yips by identifying and quantifying the kinematic parameters of the involuntary movement component. Additionally, the value of measuring muscle activity for diagnosing the yips was tested.

The study employs a within-subject design, which allows the comparison of yips-affected putts with unaffected putts within the same participant. Six yips-affected and six unaffected experienced golfers performed 90 putts each alternating between both hands, the right hand only, and the left hand only. The putts were performed on an artificial indoor green and alternated between putts with ball and putts without ball. The putting motion was captured using a 12-camera VICON system. Additionally, muscle activity of forearm flexor and extensor groups was measured on both arms. It was found that the yips were provoked 100% reliably when putting the ball with the dominant hand only. The yips largely disappeared when there was no ball. Moreover, kinematic analyses show that a higher maximal rotation velocity and a larger number of directional changes in the affected wrist's rotation clearly distinguished the yips-affected from unaffected putts. The EMG results revealed no significant differences between yips-affected and unaffected putts. Overall the results show that putting the ball with the dominant hand only reliably provokes the yips that can be measured by the wrist's rate of rotation and the number of the rotation's directional changes.

4.2. INTRODUCTION

Imagine that you have spent years perfecting a finely-coordinated movement such as holing a golf putt. Now, imagine that this finely-coordinated movement that you have perfected over years of training suddenly becomes erratic and uncontrollable, and the harder you try the more severe the problem becomes. This might not only lead to frustration and anger, but also to a premature termination of your career (Philippen & Lobinger, 2012; Schuele & Lederman, 2004). This disruption of a finely-coordinated movement in golf, as well as in other sports, is called yips and has been defined as an involuntary muscle contraction that manifests in cramping, jerking, or freezing of a planned movement (Smith et al., 2003). To date, most knowledge about the yips comes from studies examining the putting stroke in golf (Adler et al., 2011; Smith et al., 2003; Stinear et al., 2006). In golf, the yips are often characterized by the putting movement being interrupted by a jerk and/or freezing in the forearms or hands prior to impact, sending the ball to an unpredictable destination (Sachdev, 1992).

Prevalence estimates of the yips in golf range from 26% (McDaniel, Cummings, & Shain, 1989) to 47.5% (Smith et al., 2000) in highly experienced golfers. Despite the high prevalence, few interventions have been found to effectively cope with or negate the adverse side effects associated with the yips (for an exception see Bell, Skinner, & Halbrook, 2011). This lack of effective interventions can partly be attributed to the lack of understanding regarding the underlying mechanisms behind the yips. Some authors have suggested that the yips is a form of task-specific focal dystonia (Adler, Crews, Hentz, Smith, & Caviness, 2005; McDaniel et al., 1989; Sachdev, 1992). Focal dystonia (FD) is a neuropathological movement disorder often affecting finely-coordinated movements that are intensively and repetitively practiced, such as playing an instrument (e.g., musician's cramp; for a review see Jabusch, 2006), and is sometimes also referred to as occupational cramp (Byl, 2006). Others have suggested that the yips might be a chronic form of choking (Masters & Maxwell, 2008), which is a performance deterioration in response to a situation of perceived high pressure (for a review see Hill, Hanton, Matthews, & Fleming, 2010). Further still, some have suggested that the yips might exist on a continuum between FD (Type 1 yips) and choking (Type 2 yips; Smith et al., 2003; Stinear et al., 2006).

One reason for the lack of clarity regarding the underlying mechanisms of the yips is the fact that the literature is not clear on how exactly the yips are to be identified or measured. This not only makes it more difficult to diagnose, but moreover, it makes it more difficult to distinguish the yips from solely bad putting technique. In the present study we will present a method to diagnose the yips and also to quantify it by establishing kinematic parameters that distinguish the yips from simply bad putting.

A few pioneering studies have already provided valuable information about the potential kinematic characteristics of the yips. Yet, due to their methods one cannot conclude with certainty that the kinematic differences they have found between yips-affected and unaffected golfers describe the involuntary component of the putting movement that is the yips, per definition. In a study by Marquardt (2009), 19 yips-affected golfers were compared to 224 unaffected experienced golfers . In this study, yips were defined as an inconsistent oscillating movement (i.e., at least one excessive opening and closing action of the clubface) of the clubface before ball contact. The kinematic analysis revealed a significant difference in the mean rate of clubface rotation at impact, with yips-affected golfers showing a lower rate of rotation, yet significantly more variability in rotation rate inconsistency. Additionally, the yips-affected group showed a more inconsistent clubface angle and arc of club path at impact. The results indicate that the yips movement can be associated with a less consistent directional control of the clubface. The analysis, however, was limited to the moment of impact with the ball. Yet, the yips already begins before the impact, for instance as an excessive opening and closing action of the clubface (Marquardt, 2009). Thus, the inconsistency at the moment of impact might only be a consequence of the actual involuntary movement component of the yips. Therefore, considering the movement phase before the impact might provide a more accurate description of the yips kinematics and the problem with directional control. In this regard, Adler et al. (2011) showed that yips-affected golfers have more angular movement in wrist pronation/supination than unaffected golfers throughout the putting motion. Altogether, it seems that the main visible characteristic of the yips is related to the rotation of the wrist, and thus, the clubface around the moment of impact with the ball. Whether these kinematic differences, however, describe the involuntary movement which comprises the yips, or just describe a general difference in technical execution of the putting stroke between yips-affected and unaffected golfers cannot be concluded due to the between-subject design of the studies.

Both of the aforementioned studies employed an inter-individual design and thus, the differences that have been found could simply describe individual differences in the execution of the putting stroke. Furthermore, neither study reports the number of yips occurrences; thus, it is not clear how often participants actually experienced the yips. As Adler et al. (2011) reported, the self-assignment of yips-affected or unaffected participants was not valid in their study and not all yips-affected participants experienced the yips in every putt. Both factors may potentially confound the mean results, and do not allow the conclusion that the detected differences are directly related to the yips, rather than general differences in skill execution between yips-affected and unaffected golfers. To measure the typical yips symptoms, it is necessary to compare the kinematics of two very similar putting movements, one with yips and one without yips, within the same person. Only this way will we be able to detect the involuntary movement component that is at the core of the definition of the yips.

One way to create a situation in which the identical movement can be performed with and without yips might be performing the putting movement with and without the ball. Filmalter et al. (2008) showed in a single case, single trial that a yips-affected golfer’s rotation parameters were very similar to the undisturbed putting movement of unaffected golfers when there was no ball present while putting. Thus, in the present study putts with the ball are compared to putts without the ball.

In addition to this comparison, the present study is the first to examine putts that are only performed with one hand. Putting with only one hand at a time is also helpful to determine which hand is affected, a question that has not been addressed by physical tests, but only by questionnaires reporting that the majority of yips-affected participants were only affected in one hand (McDaniel et al., 1989). Having participants perform putts with only one hand eliminates potential compensating behavior from the other (e.g., unaffected) hand and therefore, likely allows an undisturbed observation of the physical manifestation of the yips.

A single-handed putting procedure that allows the intra-individual comparison of identical movements with yips and without yips might also serve to test the diagnostic validity of alternative measurements that have previously been employed in investigating the yips. For instance, it has been reported that two specific electromyography (EMG) parameters show differences between yips-affected golfers and unaffected golfers (Adler et al., 2005, 2011; Smith et al., 2000; Stinear et al., 2006). First, the mean peak root mean square (rms) EMG activity in the forearm muscle groups (i.e., wrist extensor and flexor) was higher in the yips-affected golfers, which is often attributed to a dysfunctional inhibition, which is a typical symptom of FD (Smith et al., 2000; Stinear et al., 2006). Second, a trend for more co-contractions of wrist flexor and extensor muscle groups in yips-affected golfers have been found (Adler et al., 2005, 2011). This was argued to support FD as the underlying cause of the yips symptoms in some of the golfers, since co-contractions are a hallmark of FDs.

Both of these EMG findings and their interpretations, however, suffer from a few shortcomings that make their usefulness in diagnosing the yips less clear. First, the higher EMG activity was only found in the left arm (Smith et al., 2000; Stinear et al., 2006), yet reports indicate that the yips affect the dominant arm more often (Philippen & Lobinger, 2010). Given that the majority of the participants were right-handed, it seems likely that the higher activity in the left arm is a result of compensating behavior to counteract the effect of the involuntary action in the affected right arm. Second, co-contractions do not occur in all dystonic patients (Latash, 1998), and have also been found in unaffected golfers (Adler et al., 2011) as well as in expert participants without pathological movement disruptions when performing under high pressure (Yoshie, Kudo, Murakoshi, & Ohtsuki, 2009). Generally, co-contractions of antagonistic muscle groups function to stabilize joints against perturbations (Latash, 1998). Thus, co-contractions are a rather ambivalent indicator of yips. Although differences in EMG measurements have been found between groups of yips-affected golfers and unaffected golfers, it is not clear in how far these differences are a direct consequence of the underlying yips mechanisms or just the consequence of attempts to control the involuntary movements.

By eliminating compensatory behavior from the unaffected arm and intra-individually comparing identical movements with and without yips, we expect to draw a clearer picture of the usefulness of EMG measures in describing the yips in golf putting. In addition to the EMG measurement, we use the aforementioned design to assess the distinctive kinematics of the yips in order to objectively describe and measure the movement disorder. Based on previous research, we expect that the putting movement without the ball will be free of yips and that the yips will mainly occur in the participants' dominant arm. Furthermore, we will test which kinematic parameters best reflect differences between yips and yips free movements. As has been shown, the yips is mainly related to problems with the rotational and directional control of the clubface. Therefore, we will focus on rotational parameters in the comparison of yips-affected and unaffected putts.

We compare putts with the ball and without the ball in order to create a situation that allows for the comparison of yips-affected putts with unaffected putts. Although putting movements without the ball (i.e., practice putts) are often performed before the real putt (i.e., with the ball) on the golf course and are supposed to be identical to the real putts, it is not guaranteed that it is indeed the same movement. In order to treat the real putts and practice putts as identical movements, and therefore justify the comparison between yips-affected and unaffected putts, we will compare kinematic parameters of real and practice putts that are deemed relevant for successful movement execution and are indicative of technical quality (Pelz & Frank, 2000). This comparison will additionally include a group of expert golfers in order to test if the results also account for the unaffected golfers in our sample. This is important because the unaffected group serves as a control group in later EMG analyses, testing the influence of the ball's presence on muscle activity in order to exclude potential confounds from the yips. Only in the event that there are no significant differences in the technical execution of real and practice putts in the unaffected group, a comparison of muscle activity between real and practice putts is warranted. We hypothesize that the movement execution of real putts is not significantly different from practice putts, neither for yips-affected nor unaffected golfers, because in golf the practice putt is supposed to be a simulation of the real putt in order to observe any mistakes and get a feeling for the subsequent real putt.

4.3. Method

4.3.1. PARTICIPANTS

Participants were 12 right-handed male golfers. Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971). Based on self-reports, participants were categorized as yips-affected (*n* = 6) or unaffected golfers (*n* = 6). The yips-affected golfers' mean age was 45.83 (*SD* = 16.39) years, they had a mean handicap of 17.9 (*SD* = 20.9) strokes and had played golf for 14.33 (*SD* = 9.24) years. According to self-reports, they were affected by the yips for a mean of 9.9 (*SD* = 6.4) years. The unaffected golfers' mean age was 42.83 (*SD* = 10.4) years, they had a mean handicap of 5 (*SD* = 5.1) strokes and had played golf for 21.17 (*SD* = 8.11) years. All golfers gave their written informed consent in accordance with the declaration of Helsinki.

4.3.2. APPARATUS

The putting motion was captured with 12 MX-F20 CCD cameras (Vicon Motion Systems, Oxford, UK) with 200 Hz temporal resolution and approximately 0.25 mm spatial resolution. The system uses infrared diodes around the lens of each camera that emit infrared light, which is then reflected by round retro reflective markers and captured by the cameras. Cartesian coordinates of the retro reflective markers were calculated by triangulation. The markers were placed at the golf putter's heel, toe, and in the middle of the clubhead. Additional markers were placed at participants' relevant joint axis according to the locations of the VICON plug-in gait model ("Plug-In Gait", 2012). One marker was placed on each shoulder right above the acromion. On each elbow, two markers were placed at the epicondyle, one lateral and one medial. Two markers were placed on each wrist, one at the capitulum radialis and one at the capitulum ulnaris. Per foot, one marker was placed on the very front top part of the shoes. Additionally, the putting motion was videotaped using a high-speed camera (Basler AG, Ahrensburg, Germany) at a sampling rate of 100 Hz.

Surface EMG was recorded from left and right wrist extensor and flexor muscle groups. Following standard skin preparation techniques, electrodes (Ambu Blue Sensor N-electrodes) were placed on the extensor carpi radialis (ECR) and flexor carpi radialis (FCR). The signal was actively amplified 1000 times and wirelessly transmitted via radio transmitter (Myon, Zurich, CH). The transmitters were connected to the electrodes and taped to the forearm at an unobtrusive location. The signal was recorded with the software Vicon Nexus 1.7.1 (Vicon Motion Systems, Oxford, UK). The sampling rate was 2000 Hz.

4.3.3. EXIT INTERVIEW

Upon completion of the experiment, participants were asked if they had experienced any past movement disorders other than the yips, or if they had any family members who have had movement disorders. If the participants experienced the yips during the experiment, they were additionally asked if this experience was similar to the yips they experienced on the golf course. Finally, they were asked to rate the severity of the yips on a Likert-scale ranging from 1 to 10, with verbal anchors at 1 (*very low*) and 10 (*very high*).

4.3.4. PROCEDURE

Participants were briefed and asked to sign the informed consent and fill in the Edinburgh Handedness Inventory. Next, participants were prepared for EMG and kinematic measurements according to standardized electrode application procedures (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). No a priori normalization procedures (e.g., maximum voluntary contraction) were necessary due to the within-subject design of the study.

Participants were asked to putt from 1.5 meters distance on an artificial indoor turf toward a standard size golf cup (ø = 10.8 cm) using a conventional putting grip (i.e., left hand on top). The starting point of the ball was marked by a small black dot on the putting green. After every putt, the ball was returned to the starting point by the researcher.

Participants underwent three conditions. In the first condition, participants putted with two hands (2H) using the conventional putting grip. In the second condition, participants putted with only their right hand (RH). In the third condition, participants putted with only their left hand (LH). The order of conditions was the same for all participants. In each condition, participants alternated between putting without a ball (i.e., practice putt) and putting with a ball (i.e., real putt), with the practice putt always occurring before the real putt. Both the practice and real putts were performed 15 times each. Thus, per participant there was a total of 90 putts (with and without the ball). Participants were instructed and regularly reminded to report after every putt whether or not they had experienced the yips.

Before the start of the 2H condition, participants putted five times to familiarize with the situation and the equipment. Before the start of the RH and LH conditions, participants putted 3 times each to familiarize with the new task. After completion of the putting task, participants underwent the exit interview and were subsequently thanked and dismissed.

4.3.5. DATA REDUCTION

4.3.5.1. Kinematic data.

Marker trajectories were labeled manually and smoothed using a built-in Woltring filter with a value of 1 in Vicon Nexus 1.7.1 (Vicon Motion Systems, Oxford, UK) and exported to MATLAB (2010b, The MathWorks, Natick, MA) for post processing. Labeling was checked by visual inspection of the plotted trajectories. The technical parameters used to assess putting technique and the parameters used for analysis of the yips were calculated from the start of the movement (i.e., the moment the club started the backswing) until the end of the movement (i.e., the moment that the clubhead ceased to move forward). These parameters are described in Table 4.1. The technical parameters were derived from the teaching literature (Pelz & Frank, 2000) and our biomechanical understanding of the putting movement; they consisted of four setup parameters and eight swing parameters, which have been identified as relevant for the successful execution of the putting stroke (Pelz & Frank, 2000).

For the practice putts, we determined a timeframe that served as the virtual moment of impact with the ball. The time frame was calculated by taking the mean location of the clubhead at the moment of impact with the ball across all real putts within the same hand condition and within the same participant. Next, the time frame of virtual impact with the ball was assessed by taking the timeframe when the clubhead reached the mean location.

4.3.5.2. EMG data.

EMG data was analyzed using MATLAB (2010b, The MathWorks, Natick, MA). Fast-Fourier-transformations were plotted and visually inspected for artifacts or distortion of the signal. A 10 - 500 Hz Butterworth filter was applied and each EMG trace was rectified. The rms EMG values were calculated over 50ms time frames for the complete length of each trial. Further analysis of the EMG signal was restricted to the period from the start of the backswing until the end of the forward swing (i.e., only the putting movement). Peak rms EMG activity and mean rms EMG activity was calculated per muscle, per participant, and per condition across all putts.

4.3.5.3. Yips ratings.

To identify the putts during which the yips occurred, two raters independently rated the high-speed videos of every putt. The procedure "was based on the premise that a movement disorder is diagnosed on examination findings of involuntary movements and not on the subjective complaint of a movement disorder" (Adler et al., 2011, p. 1994). The videos were played in slow-motion (20% of real speed). The raters judged whether they could observe a sudden twisting, jerking, shaking, or freezing of either arm, disrupting the smooth forward swing of the putting motion. The putts were rated as either yips or no yips. To increase the accuracy of the yips rating, the inter-rater ratings were compared with participants' self-ratings. Putts were only rated as yips or no yips putts when all ratings agreed. All putts that could not be rated unambiguously were excluded from further analysis.

Table 4.1. - List of the Kinematic Parameters of the Putting Movement Categorized According to Setup Phase, Swing Phase, and Yips Characteristics

Parameter	Description (unit of measurement)
ANGLEstartC	Angle (°) between clubface and BHL
ANGLEstartW	Angle (°) between right wrist and BHL
ANGLEstartSHO	Angle (°) between line connecting shoulders and BHL
ANGLEstartFEET	Angle (°) between line connecting feet and BHL
SwingRatio	Duration (sec.) of backswing divided by duration of forward swing
CHmaxSpeed	Maximum club head velocity (m/s) during forward swing
CHPATHip	Angle (°) between path of the club and BHL at impact
ANGLEipC	Angle (°) between clubface and BHL at impact
ANGLEipW	Angle (°) between right wrist and BHL at impact
ANGLEipSHO	Angle (°) between line connecting shoulders and BHL at impact
ΔANGLEforeswingC	Difference between angle (°) of clubface relative to BHL at the start moment and end moment of fore swing
ΔANGLEforeswingSHO	Difference between angle (°) of line connecting shoulders relative to BHL at the start moment and end moment of forward swing
RVmaxC	Maximal rotation velocity (°/s) of clubface in relation to BHL
RVmaxW	Maximal rotation velocity (°/s) of right wrist in local coordinate system of the wrist
No&cC	Number of opening and closing action of clubface in relation to BHL
No&cW	Number of opening and closing action of the right wrist in local coordination system of the wrist
ROTmaxC	Maximal rotation (°) of clubface within one opening or closing action
ROTmaxW	Maximal rotation (°) of right wrist within one opening or closing action

Note. All angles are measured in degrees; BHL = Ball-Hole Line, indicates the straight spatial connection between the middle of the ball and the middle of the hole; opening and closing actions are defined as a change of rotational direction. All setup parameters are measured at the start of the backswing. All swing and all yips parameters are measured throughout the entire foreswing.

4.3.6. STATISTICAL ANALYSES

In order to compare the yips parameters and technical parameters between different conditions within the same participants, we calculated the mean values per participant for each relevant condition for all parameters. Please note that the analyses were restricted to the RH condition, because as the yips ratings show, only this condition provided a sufficiently balanced distribution of yips-affected and yips-free putts to allow any statistical comparisons.

To test if the yips parameters were significantly different between yips-affected putts and unaffected putts, we conducted three separate repeated measures multivariate analysis of variance (RM MANOVA) with yips occurrence (yips vs. yips-free) as a within-subject factor for three categories of dependent variables: (a) maximum rotational velocity (RVmax) of the clubface (RVmaxC) and the wrist (RVmaxW); (b) frequency of opening and closing (No&c) of the clubface (No&c) and the wrist (No&cW); and (c) maximum rotation (ROTmax) of the clubface (ROTmaxC) and the wrist (ROTmaxW) within one opening or closing motion. Only yips-affected golfers were included in these analyses.

To test if there were any differences in the technical execution of the putting movement between real and practice putts, two RM MANOVAs were performed with the factor ball (putts with a ball vs. putts without a ball). The setup parameters were included as dependent variables in the first RM MANOVA and the swing parameters were included as dependent variables in the second RM MANOVA. The analyses were run across all participants, including the unaffected group. This is important because the unaffected group served as a control group in later EMG analyses, testing the influence of the ball's presence on muscle activity and excluding potential confounds from the yips. A comparison of muscle activity between real and practice putts is warranted only if there are no significant differences in the technical execution of real and practice putts in the unaffected group.

In order to compare the mean and peak EMG values between yips-affected putts and unaffected putts, we calculated the mean values for all parameters per participant, muscle, and type of putt (yips-affected vs. unaffected and real putt vs. practice putt). The mean values of the yips-affected participants were subjected to a RM MANOVA with yips (yips-affected putts vs. unaffected putts) as a within-subject factor and the peak and mean EMG values per extensor and flexor as the four dependent variables. In order to test the influence of the presence or absence of the ball on the mean and peak EMG values of extensor and flexor muscle groups while putting, we conducted a RM MANOVA with ball (real putt vs. practice putt) as within-subject factor. This RM MANOVA was only run for the data of the unaffected participants in order to eliminate any influences of yips on the muscle activity. This analysis was necessary in order to test if EMG values are generally different between real and practice putts, which could confound the results of the comparison between yips-affected and yips-free putts.

4.4. RESULTS

4.4.1. YIPS RATINGS

The initial inter-rater agreement was 98.3% for the 2H condition, 96.4% for the RH condition, and 100% for the LH condition. After discussion of the discrepant ratings, the raters agreed on all putts in the 2H and LH condition and on 99.4% in the RH condition. The cross validation between the inter-rater agreement and participants' self-rating resulted in a final rating agreement of 94.4% in the 2H and RH condition, and 100% agreement in the LH condition.

The results revealed that there were no yips-affected putts in the unaffected group. Moreover, the results show that all participants from the yips-affected group experienced the yips on 100 % of the real putts (i.e., with the ball) when putting with the right hand only. In the RH practice putt condition only 10 % of all putts were affected by the yips. In this condition, only three participants experienced the yips, with a frequency ranging from one to five times per 15 right-handed putts. In the 2H real putt condition, only 12.5 % of all putts were affected by the yips. In this condition only two participants experienced the yips, twice and eight times, respectively. In the 2H practice putt condition and in both LH conditions (i.e., practice and real putt) no yips occurred at all.

Since the RH condition was the only condition in which yips putts and yips-free putts occurred repeatedly across several participants, further analysis of the yips parameter employing a within-subject design are restricted to putts from the RH condition.

4.4.2. KINEMATIC PARAMETERS

4.4.2.1. Yips parameters.

RVmax. The RM MANOVA revealed a significant main effect for yips on the maximal rotation velocity, $F(2, 4) = 21.27$, $p = .007$, $\eta_p^2 = .91$. Bonferroni corrected post-hoc repeated measures analyses of variance (RM ANOVA) revealed a significant main effect of yips on RVmaxC, $F(1, 5) = 23.04$, $p = .005$, $\eta_p^2 = .82$, showing that participants rotate the clubface significantly faster during a yips putt ($M = 296.43$, $SD = 141.48$) than during a yips-free putt ($M = 34.1$, $SD = 12.12$). However, there was only a trend for a significant difference in maximum rotation velocity of the wrist (RVmaxW) between yips putts ($M = 205.19$, $SD = 35.31$) and yips-free putts ($M = 35.31$, $SD = 23.2$), $F(1, 5) = 9.16$, $p = .029$, $\eta_p^2 = .65$.

No&c. The RM MANOVA revealed a significant main effect for yips on the number of opening and closing actions, $F(2, 4) = 20.09$, $p = .008$, $\eta_p^2 = .9$. Bonferroni corrected post-hoc RM ANOVAs revealed a significant main effect for yips on the number of opening and closing actions of the clubface, $F(1, 5) = 37.81$, $p = .002$, $\eta_p^2 = .88$ and of the wrist, $F(1, 5) = 34.94$, $p = .002$, $\eta_p^2 = .88$. The results show that participants opened and closed the clubface and their wrist significantly more often during a yips putt (clubface: $M = 6.0$, $SD = 1.46$; wrist: $M = 7.05$, $SD = 1.25$) than during a yips-free putt (clubface: $M = 1.44$, $SD = 1.01$; wrist: $M = 2.91$, $SD = 1.03$).

ROTmax. The RM MANOVA revealed no significant effect for yips, $F(2, 4) = 20.09$, $p = 0.139$, $\eta_p^2 = .63$. Furthermore, Bonferroni corrected post-hoc RM ANOVAs revealed that neither the maximal rotation of the clubface ROTmaxC, $F(1, 5) = 2.47$, $p = .177$, $\eta_p^2 = .33$, nor the maximal rotation of the wrist ROTmaxW, $F(1, 5) = 8.14$, $p = .036$, $\eta_p^2 = .62$ differed between yips putts and yips-free putts. The results show that participants did not rotate their clubface or wrist significantly further during a yips putt (clubface: $M = 22.01$, $SD = 7.41$; wrist: $M = 14.71$, $SD = 7.69$) than during a yips-free putt (clubface: $M = 15.09$, $SD = 7.54$; wrist: $M = 7.61$, $SD = 2.31$)[2].

4.4.2.2. Technical parameters.

The yips rating revealed that the yips occurred in all right-handed putts of all yips participants when trying to hit the ball, but only occurred rarely in a few of the

[2] An exemplary video illustrating the typical yips motion in one handed putting can be seen under the following link: http://www.uni-bielefeld.de/(en)/sport/arbeitsbereiche/ab_ii/research/sml-lab/errors_in_skilled_complex_actions.html

yips-affected golfers during the practice putts. This distribution of yips-affected and yips-free putts rendered the comparison of yips-affected vs. unaffected putts basically to a comparison between putts with the ball vs. putts without the ball. It is possible that the movement of real putts differ from that of a practice putt, which might have led to the differences found in the yips parameters. Only if the movement in both conditions are similar, then our aforementioned comparison of yips-affected and yips-free putts can be considered to describe the kinematic differences directly related to the yips, and would not be confounded by any technical differences in movement execution between real and practice putts. Therefore, we tested whether or not participants showed a similar general technical performance during real putts and practice putts in the RH condition. For this comparison, we included all participants of both groups (i.e., yips-affected and unaffected), to test if the real and practice putts were also performed alike in the unaffected group.

The mean descriptive results are listed in Table 4.2. Two RM MANOVAs were performed, one to compare the setup parameters, and one to compare the swing parameters between real and practice putts.

Table 4.2. - Means (SDs) of All Kinematic Setup and Swing Parameters for Real Putts and Practice Putts in the Right Hand Condition Across All Participants, and *p*-Values and Effect Sizes (η_p^2) for the Post-Hoc ANOVAs

Parameter	*N*	Ball	No ball	*p*-value (η_p^2)
ANGLEstartC	12	88.43 (1.21)	88.21 (0.95)	.383 (.07)
ANGLEstartW	12	82.5 (10.26)	81.34 (10.9)	.281 (.11)
ANGLEstartSHO	12	-7.74 (3.67)	-8.19 (3.52)	.244 (.12)
ANGLEstartFEET	12	-1.68 (2.27)	-1.71 (2.35)	.586 (.03)
SwingRatio	12	0.8 (0.1)	0.76 (0.18)	.442 (.06)
CHmaxSpeed	12	1.19 (0.13)	1.25 (0.32)	.482 (.05)
CHPATHip	12	0.79 (2.11)	0.46 (1.39)	.451 (.05)
ANGLEipC	12	90.32 (2.02)	90.88 (1.89)	.226 (.13)
ANGLEipW	12	82.7 (10.58)	82.39 (11.18)	.772 (.01)
ANGLEipSHO	12	-7.98 (4.4)	-8.58 (3.65)	.242 (.12)
ΔANGLEforeswingC	12	17.9 (7.14)	14.86 (7.9)	.264 (.11)
ΔANGLEforeswingSHO	12	6.89 (3.56)	7.7 (2.28)	.443 (.06)

The RM MANOVA with the setup parameters ANGLEstartC, ANGLEstartW, ANGLEstartSHO, and ANGLEstartFEET as dependent variables revealed no significant differences between putts with or without a ball, $F(4, 8) = 0.89$, $p = .513$, $\eta_p^2 = .31$. Post-hoc Bonferroni corrected RM ANOVA results for all setup parameters are depicted in Table 4.2. The results indicated that none of the setup parameters differ between real putts and practice putts. This shows that the setup for a putt with a ball is generally similar to the setup for a putt without a ball.

The RM MANOVA with the swing parameters SwingRatio, CHmaxSpeed, CHPATHip, ANGLEipC, ANGLEipW, ANGLEipSHO, ΔANGLEforeswingC, and ΔANGLEforeswingSHO as dependent variables revealed no significant differences between putts with and without a ball, $F(8, 4) = 4.3$, $p = .087$, $\eta_p^2 = .896$. Post-hoc Bonferroni corrected RM ANOVA results for all swing parameters are depicted in Table 4.2. The results indicated that none of the swing parameters differed between real putts and practice putts. This indicates that the swing execution of a putt with a ball is generally similar to the execution of a putt without a ball within the same participant.

Please note that we also tested both groups separately using single RM ANOVAs per parameter in order to control for confounding effects from any of the groups. The results revealed no significant differences between real and practice putts for either group.

4.4.3. EMG PARAMETERS

Peak and mean rms EMG values are presented per muscle and per condition in Table 4.3. To compare the EMG values between a yips-affected and an unaffected putt within the same participant, we conducted a RM MANOVA with the factor yips (yips-affected putt vs. yips-free putt) and the peak and mean rms EMG values per extensor and flexor as the four dependent variables. The analysis included only the yips-affected participants. The results revealed a main effect for yips, $F(4, 2) = 32.15$, $p = .03$, $\eta_p^2 = .985$. Post-hoc Bonferroni corrected RM ANOVAs, however, revealed no significant effect for yips on any of the dependent variables. The p-values and effect sizes are presented in Table 4.3. Despite no significant EMG activity differences between yips-affected and yips-free putts, it is noteworthy that the mean peak activity across all yips-affected participants has a tendency to be higher in yips-affected putts than unaffected putts. Also, there is more variation of mean peak activity across yips-affected putts than across unaffected putts. This high variation in combination with the small sample size also influences the p-value, which in the current case might lead to an increased likelihood of a type 2 error.

To test if the presence of and potentially the impact with the ball had a significant effect on the EMG activity, we compared the peak and mean EMG activity of wrist flexor and extensor muscles between real putts and practice putts. In order to eliminate potential influences from the yips, we only analyzed the data from the unaffected group. A RM MANOVA with the factor ball (with ball vs. without ball) and the peak and mean EMG values per extensor and flexor as the four dependent variables revealed no significant effect, $F(4, 2) = 2.91$, $p = .27$, $\eta_p^2 = .85$. The descriptive values per muscle and the p-values and effect sizes of the post-hoc RM ANOVAs are presented in Table 4.3. The results indicate that there are no significant differences in peak and mean EMG of the wrist flexors and extensors between real putts and practice putts.

Table 4.3. - Comparison of Mean EMG Activity Per Muscle and Parameter Between Yips-Affected Putts and Unaffected Putts (only for the yips-affected group) and Between Putts With and Without the Ball (only for the unaffected group)

		Yips-affected group		
Parameter	*N*	Yips	No yips	*p*-value (η_p^2)
Extensor peak EMG	6	168.37 (133.78)	60.99 (15.7)	.097 (.45)
Extensor mean EMG	6	39.55 (14.59)	31.92 (9.2)	.178 (.33)
Flexor peak EMG	6	156.11 (75.19)	73.5 (27.94)	.023 (.68)
Flexor mean EMG	6	43.81 (15.51)	36.57 (15.84)	.072 (.51)
		Unaffected group		
Parameter	*N*	Ball	No ball	*p*-value (η_p^2)
Extensor peak EMG	6	109.71 (26.26)	115.11 (29.99)	.477 (.11)
Extensor mean EMG	6	63.32 (20.98)	67.50 (25.04)	.129 (.40)
Flexor peak EMG	6	92.10 (20.79)	76.98 (24.20)	.19 (.32)
Flexor mean EMG	6	39.93 (6.24)	38.03 (10.66)	.62 (.05)

Note. EMG values are reported in microvolts (μ)

4.4.4. EXIT INTERVIEW

None of the participants in the unaffected group reported to be affected by any movement disorders. The yips-affected participants also reported to have not experienced any movement disorders other than the yips. However, five out of the six yips-affected participants reported yips-like symptoms when striking a forehand in tennis. The sixth participant did not experience any problems while playing tennis, but has not played since he started playing golf. All participants reported that the yips symptoms they experienced during the experiment were identical to the symptoms they experience in the field. On average, the yips severity was rated 7.17 (*SD* = 2.64) on a 10-point Likert scale.

4.5. Discussion

The purpose of the present study was to identify kinematic parameters that describe yips symptoms and allow an objective measurement of the yips. The yips is per definition an involuntary muscle contraction that manifests in the disruption of a planned movement. Thus, a kinematic description of the yips needs to describe by definition the involuntary movement component. The within-subject comparison of yips-affected and unaffected putting movements revealed that the main kinematic differences between the two movements can be described by multiple pronation and supination movements of the arm's wrist. These rotations occurred at very high velocity relative to the yips-free putts. The yips in putting could thus be described as an involuntary rotation of the clubface and wrist, which changes direction a number of times at high velocity. This description complements previous kinematic descriptions of the yips, which indicated that the yips are related to disruptions of directional control (Adler et al., 2011; Marquardt, 2009). The present study is the first to investigate the yips applying a within-subject design, and therefore the first study to allow the conclusion that the kinematic differences that have been found are directly related to the yips and not to any general differences in technical execution of the putting movement between two groups. Moreover, the present results contradict the argument that the yips are solely bad putting technique, since all yips-affected participants were able to perform the putting movement without yips. Furthermore, the current results extend the previous kinematic descriptions by providing kinematic parameters for the measurement of yips that go beyond the moment of impact, and rather describe the physical manifestations of the yips throughout the entire putting motion. Although Adler et al. (2011) also investigated the entire putting motion, they did not report maximal rotation velocity or the numbers of opening and closing actions. Unlike Adler et al., we did not find significant differences in the peak angular displacement of pronation or supination movements between yips-affected and unaffected putts, although the present results show that there is a tendency for more angular displacement in yips-affected putts. The variation in findings possibly emerges from the difference experimental design. A notable contribution of the present study is the investigation of putts performed with only one hand.

In the present study, putts performed with only the dominant right hand were investigated, whereas all previous studies only had participants perform putts with both hands. Putting with only the affected hand provides a number of advantages for further research on the yips. Firstly, it allows for the assessment of the yips symptoms without any interference from compensating behavior of the second unaffected hand, which may mask the yips movement. Secondly, putting with only the affected hand seems to reliably produce the yips in affected participants. The reliable occurrence of yips in laboratory settings has been a main problem with investigating the yips (Adler et al., 2011). It is difficult to investigate effects of experimental manipulations or interventions when the yips only occurs occasionally or even not at all while putting with two hands in the laboratory. Our results suggest that future studies can utilize having participants perform the putt with the affected hand only in order to look for changes induced by experimental manipulations or interventions.

Aside from contributing a kinematic description of the yips, the present study also compared the peak and mean rms EMG activity of wrist extensors and flexors between yips-affected and unaffected putts within the same participant. Contrary to previous studies (Smith et al., 2000; Stinear et al., 2006), we found no significant differences in EMG activity. One explanation may be that participants in the present study only putted with the affected right hand. Previous studies found in particular higher peak activity in the left forearm instead of in the more likely affected right (dominant) arm (Stinear et al., 2006). The higher muscle activity of the left arm is likely due to an attempt to compensate the involuntary rotation of the right wrist and clubface. EMG data has indicated only a tendency for higher peak EMG activity in yips-affected putts despite the clear kinematic differences between yips-affected and yips-free putts, thus we might question its diagnostic value. Based on the current results, EMG measurements of the wrist's flexor and extensor muscles are not a sensitive enough measurement to distinguish yips-affected putts from yips-free putts. Given that the involuntary movement component is a rotation of the wrist, it might be more meaningful to measure the activity of muscles responsible for pronation and supination movement rather than flexion or extension. Noteworthy, however, is the tendency for peak EMG of extensor and flexor muscles to be higher in yips-affected putts, which might not have reached significance because of the small sample size.

The small sample size is the main limitation of the present study. However, while the relative power of the study was low, clear differences emerged between kinematic parameters that differentiate between yips-affected and unaffected putts. The high effect sizes for the number of opening and closing actions and the maximal rotation velocity indicate the strong impact the yips has on these parameters. Thus, despite the small sample size, arguing that these parameters allow for an objective measurement of the yips seems valid. It is, however, possible that the involuntary contractions that define the yips also manifest in other ways than what is observed here. Yet, because all participants showed very similar kinematic symptoms of the yips, and also because previous studies indicated that the yips in putting is associated with a disruption of directional control and rotations of the wrist and clubface (Adler et al., 2011; Marquardt, 2009), we argue that the present study provides a kinematic description of a typical manifestation of the yips in putting.

For future studies, we suggest utilizing the one-handed putting procedure established in the present study to investigate the yips. Based on the current findings, a number of interesting questions arise for future investigations. For instance, why does the presence of the ball provoke the yips with 100% reliability, whereas the same motion is completely free of yips symptoms in almost every putt without the ball? The first possible explanation relates to the anticipation of contact with the ball. The impact with the ball provides a force that participants must act upon. In anticipation of the impact, participants might tense their muscles, which might lead to involuntary contractions. However, if only the anticipation of the ball's resistance would provoke the yips, then none of the participants should have experienced the yips during practice putts, yet three out of six participants experienced the yips during a practice putt at least once. Another effect of the ball is that it provides the golfer with knowledge of results. Without a ball it is hard to tell whether the putt was successful or not. The ball enables the evaluation of the performance, and thus might increase the psychological stress that participants experience, which is generally acknowledged to worsens the symptoms of the yips (Smith et al., 2003). Consequently, the prospective of evaluation of performance might provoke the yips symptoms a priori. However, again this explanation could not account for the fact that three golfers experienced the yips while putting without the ball. The third effect of the ball is that it provides a spatial reference point for the directional control of the putting movement. Golfers learn to make a square impact with the ball in order to send the ball straight down the aiming line (i.e., line between the ball and hole). Having such a reference point allows for anticipation of the clubface angle at the moment of impact, especially during such slow movements as putting. The effect that a spatial reference point might have on provoking the yips can also be existent without a ball, given that the golfer picks a point on the ground as a virtual impact point. There was a small black dot on the putting green in our study, which marked the position of the ball for the experimenter. It is possible that some participants may have adopted this dot as a spatial reference point during practice putts. This could be the reason why some participants experienced the yips even without the presence of the ball. Given the trouble yips-affected golfers seem to have with controlling their clubface rotation (i.e., the directional control of the putt), it seems promising to proceed with research on the yips in this direction.

To summarize, we showed that the yips are not primarily a problem with the technical execution of the putting movement. Moreover, the study describes a method to test if someone is affected by the putting yips, and provides kinematic parameters that allow for an objective measurement of the yips. This is valuable information for applied practitioners and researchers alike. In the future, golfers can be easily tested for the yips by letting them putt with only the dominant hand with and without a ball a few times. If the smooth putting motion is disturbed by numerous openings and closings of the clubface and wrist at a high velocity when the golfer putts a ball, but not when the golfer performs a practice putt, then this golfer likely has the putting yips. In order to reach more of a consensus in future studies on the yips, we suggest redefining the yips in golf putting (and that is only in putting) as an involuntary rotation of the dominant arm's wrist at high velocity, with a number of directional changes before the impact with the ball. We hope that finding consensus on the definition of the investigated phenomenon will promote our understanding of it in the future, and consequently help all those whose long trained finely-coordinated movement has fallen victim to the yips.

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5. CHAPTER – GENERAL DISCUSSION

5.1. General Discussion

The scope of the present dissertation was on promoting the understanding of the yips in golf putting. In chapter 2, we investigated the psychological components of the yips in golf. Yips-affected golfers were interviewed about their thoughts and feelings in relation to situations in which the yips usually occur. Additionally, the participants were asked about their focus of attention right before performing a putt. The results show that the yips-affected golfers predominately associated negative thoughts and feelings with the task of putting (i.e., the yips-affected stroke). For example, the majority reported a perceived loss of control and confidence in their putting stroke, as well as anger about mistakes and anxiety about having to take a putt. These results are in line with a previous interview study on yips-affected bowlers in cricket, who also reported increased anxiety (Bawden & Maynard, 2001). Despite the reports of experiencing rather intense anxiety and the postulation that the yips are at least aggravated by severe performance anxiety (Smith et al., 2003), there seems to be no difference on the level of anxiety between yips-affected and unaffected golfers based on standardized psychometric assessments (see chapter 1.4.6.; McDaniel, Cummings, & Shain, 1989; Sachdev, 1992; Stinear et al., 2006). Consequently, it seems plausible that not just the mere level of performance anxiety is crucial for the occurrence or aggravation of the yips, but rather the way golfers cope with the performance anxiety. This thought will be elaborated further in the remaining section on potential coping mechanisms for the yips in golf (see chapter 5.5.).

In addition to the thoughts and feelings of yips-affected golfers, their focus of attention right before performing a putt was also investigated. The results revealed that the majority of the golfers either focused on technical aspects of the movement execution or on the yips and its negative performance outcomes. According to the present scientific literature on focus of attention and choking, this can be categorized as a rather dysfunctional focus of attention for the execution of well-skilled movements (Hill, Hanton, Matthews, & Fleming, 2010). A self-focus and its performance deteriorating consequences on skilled movements has been postulated as an explanation for choking under pressure (see chapter 1.4.7.2.). Thus, the present results are in line with the postulation that at least some type of yips (Type 2) is caused by the mechanisms that cause choking under pressure (Smith et al., 2003). Since our study is the first to have investigated the focus of attention in yips-affected golfers, and we only employed retrospective measures, we cannot draw any conclusions about the causes of the yips. However, together with previous postulations about the yips being a form of choking, the present results motivate further investigations of the role of attentional focus in yips-affected golfers. This could not only promote the understanding of the underlying causes, but also help to find effective interventions to cope with the yips.

In sum, the study in chapter 2 showed that psychologically dysfunctional processes are associated with the yips in golf putting. This is in line with previous postulations that the yips are at least partly psychologically caused. However, our research did not test any postulations about the underlying causes, but provided an elaborate description of the psychological experience of a relatively widespread problem in golf that has received little attention in science. The present data can provide a starting point for tailoring interventions to cope with the described dysfunctional psychological processes and examine if successful coping reduces the yips. Based on reports about imagery techniques to cure the yips (see chapter 1.4.8.; Bell, Skinner, & Fisher, 2009), we assume that cognitive and emotional control techniques could be a promising intervention to alleviate the yips symptoms in golfers. We elaborate on potential intervention strategies at a later point in this text (see chapter 5.5.)

In chapter 3, we estimated the prevalence of the yips. Unlike previous prevalence estimations of the yips, we included golfers across the entire skill range (as indicated by their handicap) in order to allow for a more accurate estimation of the yips' prevalence across the population of golfers. Previous studies restricted their estimations to highly skilled and experienced golfers, therefore drawing an incomplete picture of yips prevalence. The results of our study show that there are reports about experiencing the yips across the entire skill range, indicating that also less skilled and less experienced golfers can be affected by the yips. However, the results also show that more highly skilled and experienced golfers than less skilled and inexperienced golfers are affected by the yips. These results show that previous prevalence estimations might have been inflated by their restriction to highly skilled golfers. Yet, despite the inclusion of the entire skill range, the prevalence of the yips in golf remains high in comparison to task-specific focal dystonias (TSFD) in other areas such as music, or in the general population. One explanation for this might be the multiple causes underlying the yips symptoms. Rosenkranz et al. (2005) showed that despite similar symptoms, not all TSFDs have the same etiology. As has been proposed earlier (Smith et al., 2003), and as we have shown in the study in chapter 2, it is plausible that in addition to neurophysiological mechanisms (see chapter 1.4.7.1.), certain dysfunctional psychological processes contribute to the yips symptoms in golf. However, both mechanisms (i.e., psychological and neurophysiological) are usually only at work once a skill has become well-trained. Yet, our findings show that less skilled golfers are also affected by the yips. Thus, we propose an alternative explanation that is based on the results of a follow-up questionnaire investigating the golfers' sports history.

The follow-up questionnaire revealed that significantly more yips-affected than unaffected golfers had played a sport that, like golf, requires a coordinated hand–eye movement to intercept a ball with an object. Based on this relationship between the yips and a certain sports history, and given the findings that less skilled golfers also seem to be affected by the yips, it seems worthwhile to further explore the potential influence sports history can have on developing the yips in golf. We suggest two plausible explanations. First, playing racket sports, such as tennis or badminton, may result in a kind of overuse of one hand or arm, which triggers the onset of the yips in golf in the form of a TSFD. This is different from the previous understanding that was grounded in the belief that TSFD is caused by extensive repetitions in one specific task (Jabusch & Altenmueller, 2006). Second, the yips could be the consequence of a negative transfer or proactive interference describing the negative effect of a previously learned skill—for example, a tennis forehand swing—on a new skill—for example, a golf putt (Rose & Christina, 2006). This approach is based on the theory of sensorimotor learning, which deals with the interaction between sensorimotor feedback and motor memory during the acquisition of a motor skill. It also includes the concept of structural constraint, saying that with an increase in practice, tasks become structurally more constrained and execution becomes more and more task-specific. Consequently, motor skills become less adaptive and can only be partially transferred onto not yet learned skills, especially if implicit representations have been developed in the motor memory.

Future studies should further explore the potential relationship between certain types of sports previously played and the onset of yips in golf. In this context, the influence of the similarity of the skills, the amount of practice of the skills, and the delay between the practice of the two skills are variables that require more attention

(Tallet, Kostrubiec, & Zanone, 2004). More investigation in this direction might enable us to develop a risk profile and promote our understanding of the underlying mechanisms causing the yips.

In chapter 4, we addressed the behavioral and physiological components of the yips in golf putting. Specifically, the purpose of the study was to develop a method to diagnose and measure the yips in golf putting. For this purpose, we created a situation that allowed for the comparison of putts affected by the yips with putts unaffected by the yips following a within-subjects design. This procedure was necessary to identify the physical manifestation of the involuntary movement component of the yips-affected putts, which by definition is the yips. Additionally, we had all participants perform putts with both hands, with the left hand only, and with the right hand only. This procedure allowed us to test which hand is affected by the yips, and moreover, allowed us to measure the physical manifestation of the yips without any influences of potentially compensating behaviors from the unaffected hand. In addition to the kinematical analysis of the yips, we assessed the muscle activity of participants' forearm extensor and flexor muscle groups to evaluate the diagnostic value of electromyography (EMG) measurements for diagnosing the yips in golf putting.

The results revealed that a higher maximal rotation velocity and more directional changes of the wrist's rotation significantly differentiate the yips-affected putts from the unaffected putts in all participants. The muscle activity of the forearm flexor and extensor muscle groups did not reveal any significant differences between yips-affected and unaffected putts. It is, however, possible that our study failed to show significant differences in the EMG parameters because of its relatively low power. The mean peak activity in flexor and extensor muscle groups has a tendency to be higher in yips-affected putts than unaffected putts. Yet, compared to the high effect sizes and the significant differences for the kinematic parameters, the diagnostic value of the EMG measurements seems rather low. Given that the involuntary movement component is a rotation of the wrist, it might be more meaningful to measure the activity of muscles responsible for pronation and supination movement rather than flexion or extension.

The kinematic parameters seem to reliably serve as diagnostic criteria for the yips in golf putting. However, the results are only based on putts that were performed with the dominant (i.e., right) hand. When participants putted with only the left hand or both hands, the yips did not occur. Noteworthy, unaffected golfers showed no signs of yips, including while putting with the dominant hand only. Moreover, yips-affected participants reported that the disruption of the directional control that was observed throughout the right-handed putts was the same sort of disruption that they would experience on the golf course and is what they identify as the yips. Thus, we can be confident that what we observed in the laboratory was identical to how the yips physically manifests on the golf course. Furthermore, the study was the first to assess the isolated affected arm in yips-affected golfers, and to measure the yips as they manifest without any potentially compensating effects from the unaffected hand. The fact that the yips occurred 100% reliably when putting the ball with only the affected hand is another very important finding. From previous studies, we know that the occurrence of the yips while putting with both hands fluctuates (see chapter 1.4.3.; McDaniel et al., 1989). Particularly in the laboratory on an indoor putting green, it appears to be difficult to provoke the yips reliably while putting with both hands (Adler et al., 2011). Therefore, having participants putt with only the affected hand enables researchers to investigate the yips more efficiently under controlled settings in the laboratory.

Another noteworthy finding is that all yips-affected golfers together only showed symptoms of the yips during eight out of 90 putts without the ball, while the yips occurred on every putt with the ball. Given that there are no significant differences in the technical execution of the putts with the ball and the putts without the ball, the findings show that the yips are unlikely due to technical problems with the movement execution. Consequently, we provided three possible explanations for the role that the perception of the ball can have in provoking the yips (see chapter 4.5.). Given that some of the participants also experienced the yips during a putt without the ball, the explanation that the ball might serve as a spatial reference point for directional control seems to be most likely. Even without a ball, it is possible for participants to pick a point on the ground (e.g., the small black dot that served as a position mark for the ball in our experiment) and use it as a reference point for a virtual impact with the clubface. Having such a reference point allows for anticipation of the clubface angle at the moment of impact, especially during such slow movements as putting. Given the obvious problems with the rotation of the clubface, and thus the directional control of the putt, it seems promising to proceed with the research on the yips in this direction. We will suggest further steps to proceed in investigating the yips after we place the current findings into the context of the existing knowledge about the yips in the next section.

5.2. Extension of The State of The Art and Concluding Remarks

The present dissertation provides empirical data that extends the knowledge on a number of aspects concerning a phenomenon that is not well understood. The information generated throughout our studies extends the knowledge about the physical manifestation (see chapter 1.4.2.) and prevalence (see chapter 1.4.3.) of the yips in golf putting, as well as the demographical characteristics (see chapter 1.4.4.) and psychological characteristics (see chapter 1.4.6.) of yips-affected golfers. This new information not only advances the state of the art of the yips in golf putting in a number of important ways, but also motivates the reconsideration of the relatively widespread postulation that the yips are a form of TSFD (see chapter 1.4.7.).

Our data concerning the psychological aspects of yips-affected golfers supports postulations about psychological reasons, such as choking under pressure, as the underlying mechanisms causing the yips in golf putting (see chapter 1.4.7.2.). Furthermore, the finding that relatively inexperienced golfers also seem to be affected by the yips, and the fact that the prevalence is significantly higher than in typical TSFDs supports the suggestion of multiple underlying mechanisms (see chapter 1.4.7.3.). Additionally, the physical manifestation of the yips seems to differ from the prototypical TSFDs, such as writer's cramp or musician's cramp, which are characterized by cramps and abnormal postures (see chapter 1.4.7.1.). Thus, we argue that the yips in golf should not be regarded as a TSFD only. All of the information available at this point rather indicates other causes than TSFD. The only indication for the yips being a TSFD is the fact that for some golfers, the yips develop over time, and seem to be task-specific. Despite the fact that the etiology of prototypical TSFDs is not completely understood and also differs between types (Rosenkranz et al., 2005), we believe that it can be rather restricting to treat the yips in golf putting solely as a form of TSFD, as some authors suggest (see chapter 1.4.7.1.) We do not argue that it could not be beneficial to transfer findings from TSFD research to the yips in golf, but we argue that this needs to be done carefully, by testing whether these findings do apply to the yips as well. Moreover, we argue that treating the yips in golf as an independent phenomenon promotes the consideration of alternative explanations of the underlying mechanisms. One such alternative explanation will be elaborated next.

5.3. A New Explanation For The Underlying Mechanisms of The Yips in Golf Putting

At this point, we will go beyond the empirical data and its interpretations and postulate a new explanation for the yips in golf putting. The explanation is inspired by the findings of the present studies and the cognitive action architecture approach (CAA-A; Schack, 2004), as well as other ideas about perceptual-cognitive structures in the context of motor control (e.g., Hommel, Muesseler, Aschersleben, & Prinz, 2001; Knuf, Aschersleben, & Prinz, 2001; Raab, Johnson, & Heekeren, 2009).

As we have shown in chapter 4, the yips seem to be a problem with the directional control of the clubface around the impact point with the ball. The symptoms disappear, however, when golfers perform the putting motion without the ball. We argue that the symptoms disappear because without the ball there is no spatial reference point that allows the anticipation of the impact of the clubface with the ball. Following this argumentation, the anticipation of the impact seems to be the crucial factor in provoking the yips symptoms. So, how does the anticipation of the impact with the ball cause the rotation of the clubface (i.e., wrist)? According to CAA-A and others (e.g., Bernstein, 1967), the anticipation of a certain goal or outcome of a movement is the first step in transforming degrees of freedom into meaningful movement effects. Thus, the perception of a certain future state of a bodily posture allows the organization of the degrees of freedom in a manner that allows for the achievement of the desired future state. The exact way this organization is carried out is not completely understood (Schack, 2004). Yet, there is evidence that feedback loops (i.e., online controlled movements) play an important role in the organization of the degrees of freedom toward the anticipatory outcome (e.g., Haruno, Wolpert, & Kawato, 2001; Wolpert & Kawato, 1998). In golf putting it was shown that the forward swing and particular its pace is controlled by online control processes (Craig, Delay, Grealy, & Lee, 2000; Delay, Nougier, Orliaguet, & Coello, 1997). Basically, this means that the movement system compares the present state of the movement in a moment-to-moment fashion with the anticipatory future state, and continuously updates organization of the degrees of freedom in a functional way. The organization of the degrees of freedom does not necessarily occur consciously, and the lower the level of the control hierarchy, the less conscious control will be exercised (Schack, 2004). Moreover, the more practiced a certain movement is, the less conscious control is necessary to perform it (Fitts & Posner, 1967). This means that once a person has learned to execute a certain movement, such as swinging a golf club back and forth in a pendulum motion, for example, this person can focus on an anticipatory movement goal, and the degrees of freedom will unconsciously be organized in a way which allows for the achievement of this goal. To understand what can go wrong during this process causing the typical yips oscillating motions of the wrist, it is first important to know what golfers' movement goals are during putting.

The ultimate goal of a putting stroke in golf is to get the ball to a desired location. This requires the ball to roll a certain distance, and in a certain direction. Since the problem of the yips appears to be within the directional control, we will only focus on this. The purpose of a putt is always to start the ball off rolling on a straight line between ball and aim (the aiming line), which is not always the hole. External influences (i.e., break of the green, wind, etc.) on the path of the golf ball are conventionally controlled by the setup of the golfer. That is, the golfer decides in which direction the ball needs to start off and sets up his body (i.e., the line between both shoulders, knees, and feet) parallel to the aiming line that the ball is supposed to start off on after the impact (Pelz & Frank, 2000). This way, the directional control of the putting motion can remain the same across putts. The direction in which the ball starts off immediately after impact is determined ca. 80% by the angle of the clubface, ca. 17% by the path of the clubhead at the moment of impact, and ca. 3% by the horizontal point at which the ball impacts with the clubface (Karlsen, Smith, & Nilsson, 2008). This supports the widely accepted notion in the golf instruction literature that the *square impact* (in relation to the aiming line) of the clubface with the ball is stressed as most important in performing a successful putt (e.g., Pelz & Frank, 2000). Thus, it is very likely that golfers anticipate the square impact as one important movement goal.

We argue that one likely anticipatory movement goal of golfers is the square impact with the ball to send it off down the aiming line. Consequently, when the movement system detects at any point during the forward swing that the desired state (i.e., square impact) will not be reached, it will correct the movement in an attempt to reach the desired state. The correction and fine-tuning of coordination usually takes place in relatively close spatiotemporal proximity to the target of the movement (Elliot, Helsen, & Chua, 2001). In golf putting, final adjustment of the clubface angle would be around the moment of impact, and would be performed by the rotation of the wrists rather than the torso. The necessity to correct the clubface angle might be triggered by a suboptimal technique, for instance, an unparalleled setup or too much rotation of the torso around the vertical axis (Karlsen et al., 2008). The correction in itself is not problematic, since it is one functional mechanism to coordinate movements. In yips-affected golfers, however, we argue that somehow this correction is flawed and exaggerated. We believe that the typical yips symptoms we have observed (i.e., fast rotations of the wrist and clubface with numerous changes in direction) are exaggerated attempts to correct the movement in a way to reach the anticipated square impact. It manifests as an oscillating movement around the square impact with the ball. This assumption is supported by the fact that there are no significant differences in the clubface angle at the moment of impact between yips-affected and unaffected putts, despite significantly more directional changes of rotation at a very high velocity (see chapter 4.4.). The next question is what disrupts the functional correction of the clubface angle during the forward stroke in yips-affected golfers?

We believe that the exaggerated correctional movements (i.e., oscillating movements around impact) are caused by overactivation of the muscles, which leads to an increased level of noise, and thus error in the movement system (Schmidt & Wrisberg, 2008). Increased muscle recruitment (i.e., higher muscular activation) can lead to high muscle tension, which can negatively affect fine motor control by preventing finely-coordinated movement adjustments (Lohse, Sherwood, & Healy, 2010). That is, when the movement system of yips-affected golfers detects a need to correct the angle of the clubface, it will try to correct the angle by a rotation of the wrist, which results in an overcorrection (i.e., rotating too far) due to the overactivation of the muscles responsible for pronation and supination. Consequently, the clubface angle needs to be corrected again to achieve the desired square impact, resulting in an overcorrecting rotation of the wrist in the opposite direction. This behavior continues at least until the moment of impact with the ball, describing the oscillating rotation of the clubface and wrist around the moment of impact that we have measured in chapter 4.

The reason that we think that yips-affected participants exert more muscle activation in pronation- and supination-relevant muscle groups lies in a number of indications. However, it has not been shown unambiguously, yet. It has been shown that yips-affected participants have a higher mean heart rate while putting, and that the yips occur most frequently in high-pressure situations (see chapter 1.4.5. & 1.4.6.; Smith et al., 2000). Both findings indicate an influence of the level of arousal, which is related to an increase in muscle tension (Schmidt & Wrisberg, 2008). Additionally, the increased muscle tension in yips-affected golfers is also indicated by the higher grip force compared to unaffected golfers (see chapter 1.4.5.; Smith et al., 2000). Furthermore, several authors concluded that there are higher levels of EMG activation in yips-affected golfers than in unaffected golfers (see chapter 1.4.5.; Smith et al., 2000; Stinear et al., 2006). Although we criticized these findings for a number of reasons (see chapter 1.4.7.1.; chapter 4.2.), the possibility of group differences remains. The group differences still need to be investigated using an experimental protocol that controls for the occurrence of yips in every putt.

The fact that our study did not find significant differences in EMG activity between yips-affected and unaffected putts does not contradict our explanation of overcorrection. Firstly, we only investigated flexor and extensor muscle groups, which are not responsible for the rotation of the wrist. Secondly, we only compared the EMG activity of yips-affected golfers between yips-affected and unaffected putts. All unaffected putts, however, were putts without the ball, during which participants could not anticipate the square impact with the ball. Thus, even if participants have the same level of EMG activation during yips-affected and unaffected putts, they would only show yips symptoms if they anticipated a square impact. Thirdly, although we did not find statistically significant differences in EMG activity between yips-affected putts and unaffected putts, there were tendencies for peak EMG activity to be generally higher during yips-affected putts. Conclusively, there are tendencies for higher EMG activity in yips-affected golfers as opposed to unaffected golfers, as well as for higher EMG activity in yips-affected putts as opposed to unaffected putts. However, the results remain inconclusive due to a number of methodological shortcomings across all studies assessing the EMG activity of yips-affected golfers.

In addition to high EMG activity caused by high levels of physical arousal, the EMG activity might also be increased by psychological factors, such as the focus of attention. Several authors have shown that an internal focus of attention leads to increased EMG activity compared to an external focus on a number of different tasks, such as lifting weights, jumping high, throwing darts, and simple force production tasks (Lohse, Sherwood, & Healy, 2010, 2011; Vance, Wulf, Töllner, McNevin, & Mercer, 2004; Wulf, Dufek, Lozano, & Pettigrew, 2010; Zachry, Wulf, Mercer, & Bezodis, 2005). Also noteworthy is the finding that aside from a generally worse performance on all of these tasks, participants showed more co-contractions and increased antagonistic muscle activity during the force production task when focusing internally. Generally, the authors conclude that an internal focus of attention leads to reduced movement efficiency in the form of increased muscle activity and less economic movements (Lohse et al, 2010, 2011). We showed in chapter 2 that yips-affected golfers tend to focus internally rather than externally on the effect of the movement. Additionally, we showed that the yips-affected golfers experienced feelings of anxiety when approaching the putt. That is interesting, because it seems that when perceived pressure increases, that there is often a shift toward a more internal focus of attention (Masters & Maxwell, 2008). The proposition that an internal focus of attention is potentially responsible for the yips symptoms has been stated before (see chapter 1.4.7.2.). This proposition fits well to the findings of the present dissertation and our proposed explanation. It additionally supports the explanation for the long-term nature of the yips.

If the aforementioned psychological and physiological factors cause the distortion of the natural coordination process, which results in the yips-typical symptoms, then it seems plausible that these factors also explain the long-term nature of the yips. Similar to the suggestion of a vicious circle by Marquardt (2009), it seems plausible that the experience of yips symptoms leads to increased insecurity about one’s own skill, which in turn might promote a focus on the technical components of the movement execution, such as the square impact, in order to improve the movement execution (i.e., eliminate the yips symptoms; see also the theory of reinvestment by Masters & Maxwell, 2008). Consequently, the increased internal focus, the increased perceived pressure, and the conscious attempts to correct the movement execution establish the yips symptoms or might even worsen them.

To summarize, the present explanation of the yips proposes that the anticipation of the impact of the clubface with the ball guides the coordination of the putting stroke and the directional control of the clubface angle. The forward swing leading to the square impact is possibly controlled in a moment-to-moment fashion (i.e., online control), based on spatiotemporal information that is outside of our conscious awareness. The rotations of the clubface throughout the forward swing, which are usually functional and serve to reach the desired square impact, seem to be exaggerated in yips-affected golfers. These exaggerated rotations are likely due to higher muscle activation, which leads to more tension of the muscles, resulting in an impaired fine-coordination and more gross motoric movements. An increased level of physical and psychological arousal, as well as an internal focus, might promote the higher muscle activation. Eventually, the attempts to cope with the yips symptoms by investing in technical skill training and more focus on the execution (such as making square impact with the ball) might establish a chronic form of the yips.

5.3.1. APPLICATION OF THE NEW EXPLANATION OF THE YIPS

The present explanation of the underlying mechanisms can also account for a number of findings related to the yips in golf putting. We have already pointed out how tournaments and high-pressure situations worsen the yips symptoms. Moreover, reports show that putts from short distances are more often affected than putts from further away (see chapter 1.4.3.). We argue that the explanation therefore lies in the disturbed directional control. During short putts, the directional control of the ball's path is more essential than the distance control, whereas it is the opposite for long putts (Karlsen et al., 2008; Pelz & Frank, 2000). While putting from a distance, the main goal is to hit the ball with the proper speed to get it in close proximity of the hole. Thus, a golfer's goal for the movement execution might be less one of making a square impact, and rather one of hitting the ball with the proper speed in order to give the putt the necessary length. Additionally, it seems that there would be less experienced pressure while putting from a distance, because the outcome is not as categorically evaluated as during short putts. For short putts, the outcome is either hole or miss, success or failure, whereas for long putts the evaluation is rather closer or further away from the hole, without a clear cutoff between success or failure. Less experienced pressure and a shift of the focus toward parameters other than the square impact might allow for the execution of the putting motion without the disruptions of the directional overcorrection.

Another postulation about the yips is that higher skilled golfers are affected by the yips more often (see chapter 1.4.4. & chapter 3). We argue that this can also be explained with the aforementioned explanation of the yips. Usually, the more skilled a golfer becomes, the more the focus of skill training shifts toward the short game. In the beginning, golfers first need to learn the full swing (e.g., drive), which is a very complex movement and difficult to master (Knight, 2004). The full swing is usually the first stroke on every hole, followed by variations (e.g., pitches or chips), and only the last few strokes on every hole are putts. Only after the long game has reached a certain skill level does the putting game become more relevant to improving the score. Eventually, the putting game makes up approximately 40% of all strokes on a round of golf, and becomes the most relevant factor in improving the score (Pelz & Frank, 2000). This is partly because of its lower error tolerance as opposed to the long game. A missed putt is always an extra stroke on the scorecard, whereas a bad stroke on the fairway might be compensated with the subsequent stroke. Since the relevance of the putting game increases with the overall skill level, it might shift the focus more toward the movement execution of the putting stroke. This increased focus on the techniques of the putting stroke probably increases the focus on the square impact. The potential consequences are the yips symptoms as sketched above. If the increase in focus on the impact and conscious attempts to improve the putting technique are the explanation for why the prevalence of the yips is higher in higher skill ranges, then this could also explain why some novices also experience the yips, especially under consideration of previous sport experience as we will explain next.

In chapter 3, we showed that relatively inexperienced golfers can also be affected by the yips. This would be contradictory to the explanation of yips being a TSFD, because this would imply many years of training. If, however, we apply the present explanation, then it is plausible that the yips symptoms are also caused by the aforementioned mechanisms in inexperienced golfers. Since the natural control process is disturbed by overcorrections due to overactivation of the motion-relevant muscles, this can also occur at a lower skill level, given that there is the intention to make a square impact with the ball as well as increased muscle tension. Previous experience with movements that require similar control components such as golf putting could even promote the occurrence of yips symptoms (see chapter 3). Novice golfers (judged by golf handicap) are not necessarily novices in performing movements during which they interfere a ball with an object that they hold in their hands, such as a racket in tennis. In many of these racket sports (e.g., table tennis, badminton, tennis), relevant directional control of the ball is determined largely by the angle of the racket's face at the moment of impact. Directional control is also largely exerted by rotations of the wrist. Thus, the basic directional control principles would be similar or the same to some degree. This would also explain why certain sports experience might be related to the development of yips in golf putting (see chapter 3).

5.4. THE COGNITIVE ARCHITECTURE OF THE YIPS

At this point, the present explanation of the yips will be embedded in the framework of the CAA-A (Schack, 2004). The identification of the level(s) of movement control that might be responsible for the yips symptoms, as well as the identification of research gaps, will help to guide further research on the yips in golf putting. In terms of the CAA-A, it seems that one main reason for yips, the overactivation of the muscles, is on the lower levels of sensorimotor representation (level II) and sensorimotor control (level I). The muscular activation is guided by representation of anticipatory perceptual effects and controlled by automatic coordination processes that are directly related to the environment. At this stage of research about the yips, it is impossible to exactly place the reason for the overactivation on either of the two sensorimotor levels. It is not clear whether the high muscle activation is a consequence of maladaptive perceptual representations or a consequence of maladaptive basic control processes. A distinction between these two levels will remain difficult, since it is also postulated that they are interdependent and change depending on the stage of learning and the task at hand (Schack, 2004). For further studies, it could be helpful to identify the modality of the perceptual representations that guide the basic muscular control during the golf putt. Visual information seems intuitive (for example, anticipating the image of a square impact). However, it was shown that vision is not necessary throughout the movement execution for the successful performance of a golf putt (Land, Tenenbaum, Ward, & Marquardt, under revision). Hence, other sensory modalities (e.g., proprioception) might play an essential role in the control of the golf putt, especially on higher skill levels (Ford, Hodges, Huys, & Williams, 2006). Identifying the relevant sensory modality for the control of the muscular coordination in golf putting, and identifying the sensory modality on which yips-affected golfers rely, might tell us more about the reasons for the yips. Moreover, it might enable the development of coping strategies that focus on the adaptation of sensory input.

The reason for the yips, however, might not be restricted to the lower levels of the CAA-A. The approach proposes a vertical cooperation between the various levels. In essence, the upper levels are superimposed on the lower levels. This means that perceptual representations (level II) that guide the sensorimotor control (level I) are activated by the Basic Action Concepts (BACs) that have been formed on the level of mental representations (level III). The mental representations, in turn, are activated by the intentions of a person (level IV). Theoretically, it is thus possible that a suboptimal or dysfunctional structure of BACs leads to sensorimotor representations (level II) and control (level I) that cause the yips' typical symptoms. For example, it has been shown that a suboptimal structure of BACs is associated with suboptimal performance (Schack, Nitsch, Engel, & Heinen, 2002) and that there are clear structural differences between experts and novices on various movements (e.g., Bläsing, Tenenbaum, & Schack, 2009; Schack & Mechsner, 2006). To the best of our knowledge, there is no information on the structure of BACs underlying the golf putt in yips-affected golfers. Such an investigation might reveal systematic differences in the structure of yips-affected golfers and unaffected golfers.

Additionally, it might be possible that suboptimal or dysfunctional BACs are responsible for the yips. BACs are sequential sub-goals that serve to execute the intended movement. BACs can be stored in memory as anticipated bodily postures. Anticipated bodily postures that are inappropriate for the intention of the movement can lead to inappropriate anticipated perceptual effects, which in turn cause inappropriate sensorimotor control. For example, the intention to have a square impact with the ball might lead to the sub-goal of achieving a square impact, regardless of the resulting trajectory of the ball. Conversely, the intention to roll the ball in a straight line does not necessarily lead to sub-goals of a square impact, depending on the other relevant parameters such as club head path and impact point. Following this perspective, the intentions of a movement could be closely related to theories on focus of attention, which in the case of the yips would be in line with previous explanations (see chapter 1.4.7.2.). However, at this point this is all just speculation, and we will need more research to understand what causes the yips and how to cure it. An outlook on further studies about the yips is presented in the next section.

5.5. Outlook on Research on The Yips in Golf Putting

The present findings and our explanation of the yips motivate a number of new questions. First of all, the speculation about the possible reasons for the yips is based on the conclusion that the yips affect the directional control of the putting stroke. This conclusion is supported by our interpretation of previous studies and the results in chapter 4. Although it was clearly shown that the perception of the ball affects the yips symptoms, it is not completely evident if this is due to the ball's function as a spatiotemporal reference point for the directional control of the clubface angle. We concluded that this was the case, because in some instances golfers showed yips symptoms despite the absence of the ball. This excluded alternative explanations of the ball's function, such as being a resisting force or providing the participants with knowledge of results. However, in order to thoroughly examine the role the perception of the ball plays in provoking the yips, one could eliminate or manipulate two of the three functions the ball might have. For example, occlusion paradigms could eliminate the knowledge of results. Moreover, balls which look identical with varying weights could be used to manipulate the ball's resisting force. Furthermore, an alternative spatiotemporal reference point could be installed to investigate the effect of directional control attempts. Alternatively, instructions to either putt the ball down a straight line or to just putt it to a wide area could differentiate between directional and distance control. The effect that each of these manipulations would have on the yips symptoms would teach us more about the role the perception of the ball plays in provoking the yips.

Departing from the previous conclusion that the yips are a disruption of the directional control of the putting stroke, another central question to our explanation is whether the level of muscle activation is actually the reason for the excessive wrist rotations. To investigate the question, it would helpful to compare the normalized levels of EMG activity in the muscles responsible for pronation and supination between yips-affected and unaffected groups. Future group comparisons should ensure to avoid previous methodological shortcomings (see chapter 4) and control for the frequency of yips per participant. Alternatively, it could be fruitful to examine the effect of interventions that reduce muscle tension on the yips symptoms in affected golfers. Such interventions could be the application of drugs (e.g., Botulinum toxin) or psychosomatic techniques (e.g., progressive muscle relaxation). We assume that a reduction in muscle activity would reduce the symptoms of the yips measured by the velocity of wrist rotation and the number of directional changes.

In addition to the high levels of EMG activity, we argued that the intention to achieve a square impact plays an important role in provoking the yips. We argued that in some instances this movement (sub-) goal (i.e., BACs) might not be appropriate to fulfill the intention of putting the ball straight. That is because the square impact only accounts for 80% of the ball's initial trajectory. Yet, it might nevertheless activate control mechanisms that correct the angle of the clubface. Consequently, it could promote our understanding of the yips if we analyzed the structure of yips-affected golfers' mental representations (i.e., BACs). A comparison with reference structures of unaffected expert golfers could reveal any potential differences associated with the (sub-) goal of a square impact.

Furthermore, the effects of interventions in causing a golfer to focus on aspects other than the square impact (e.g., the end of the forward stroke, or imagining the first few centimeters of the ball path) could reveal some interesting insights about the relationship between focus of attention and the yips. Additionally, applying EMG measurements would potentially allow for conclusions about the interaction between the intentions of a movement and the sensorimotor control of it. We would expect that a focus more distal than the square impact would reduce the yips symptoms and reduce EMG activity.

Last but not least, the results of chapter 3 revealed that there is relationship between being affected by the yips and prior experience with other sports that require the interception of a ball with a hand-held object. The relationship is not well understood, yet. We suggested that potentially similar control mechanisms and movement components exist across sports. Consequently, mental representations for the directional control of a clubface might have been developed prior to the golf experience. Thus, novice golfers might already control the direction of the clubface automatically, due to previous experiences in sports with similar movement components. Therefore, the control mechanisms in novice golfers might be disturbed in the exact same way as sketched above for more experienced golfers. In order to gain more insights into the relationship between yips in golf and sports biographies, future studies could start with investigating the influence of the similarity of the skills, the amount of practice of the skills, and the delay between the practice of the two skills.

5.6. Recommendations for Practitioners

Despite the knowledge about movement errors that we gain from understanding the yips, the most relevant motivation should be to help affected athletes to cope with the yips. First of all, since it seems that relatively inexperienced golfers can also be affected by the yips, it is important for golf professionals to be sensitive to this possibility. Initial problems with the putting stroke are often corrected by the use of conventional training techniques such as repetition and instructions. However, for yips-affected golfers, this could be rather counterproductive, because more training and an increased focus on technical aspects could lead to a worsening of the yips symptoms (see chapter 1.4.7. & 5.2.). The diagnostic criteria of the putting yips had not been clear and was usually left to subjective ratings, previously. In the present dissertation, diagnostic parameters and a procedure to objectively assess the yips in golf putting were established. This does not only serve further investigations of the yips, but can also help practitioners to diagnose the yips on the golf course. To test if someone is affected by the putting yips, just have the person perform short putts with the potentially affected (probably the dominant) hand only. Alternate between real and practice putts. If a fast oscillating movement of the wrist before the moment of impact (i.e., several directional changes of the wrist rotation at very high velocity) becomes visible during real putts (i.e., putts with the ball), but usually not during practice putts (i.e., putts without the ball), then the person is likely to be affected by the yips.

Once the yips have been diagnosed, there is obviously a need for a coping strategy. We listed a number of options in chapter 1.4.8. In this section, we present a tentative coping strategy that is deducted from our aforementioned speculation about the causes of the yips. Despite the reports of intense perceived anxiety (see chapter 2) and the postulation that the yips are at least aggravated by severe performance anxiety (Smith et al., 2003), there seems to be no difference on the level of anxiety between yips-affected and unaffected golfers based on standardized psychometric assessments (see chapter 1.4.6.). Consequently, we suggested that it is not the mere level of performance anxiety that might be crucial for the occurrence or aggravation of the yips, but rather the way golfers cope with the performance anxiety. This would mean that applied sport psychologists could focus on helping athletes to cope with dysfunctional thoughts, feelings, and focus of attention. If yips-affected golfers can apply a technique to reduce their cognitive and physiological arousal prior to taking a putt, then this might lead to decreased muscle activity. As we have argued, high levels of muscle activation are responsible for the overcorrection of the clubface angle. Thus, a decrease in the levels of arousal should lead to the alleviation of the typical yips symptoms. Additionally, we suggest applying some form of attentional training. The majority of the yips-affected golfers in our study reported to focus either internally or on worries about mistakes while performing a putt (see chapter 2). Several studies have shown that an internal focus leads to more EMG activity than an external focus on the effect of the movement (Lohse et al., 2010, 2011; Vance et al., 2004; Wulf, et al., 2010; Zachry et al., 2005). Thus, a focus on more distal aspects of the putting stroke might lead to decreased muscle activity, which might help yips-affected golfers to cope with the problem.

Which coping strategy will be most effective in curing the yips is not clear at this point. The choice of the intervention should be based on the potential underlying mechanisms. It will thus be necessary to individually assess on which level the cause of the symptoms resides, given the potentially multiple etiologies of the yips. Therefore, it is necessary to further investigate the yips in golf putting in order to help yips-affected professionals and amateurs alike to get rid of the game's worst curse.

5.7. References

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