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„Sport type involvement affects executive functioning in elite athletes“

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Ich erkläre, dass ich die vorliegende Arbeit selbstständig verfasst habe und nur die ausgewiesenen Hilfsmittel verwendet habe. Diese Arbeit wurde weder an einer anderen Stelle eingereicht noch von anderen Personen vorgelegt.

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Zusammenfassung

Gegenstand: Anhand von neuesten Forschungsergebnissen konnte man feststellen, dass Spitzensportler/innen aus strategischen Sportarten und Sportarten die eine ständige Koordination mit einem Objekt oder Gegner verlangen, nachfolgend dynamische Sportarten genannt, bessere Ergebnisse bei Testverfahren zur Erfassung von Exekutiven Funktionen (EF) erzielen. Derzeit mangelt es jedoch in diesem Forschungsbereich daran zu verstehen, in wie fern sportliche oder kreative Aktivitäten während der Kindheit und Jugend zur Entwicklung dieser EF beitragen.

Methode: Siebenundfünfzig Spitzensportler/innen (36 Männer / 21 Frauen; Alter: 22.86 ±4.66 Jahre) aus der höchsten nationalen Leistungsstufe in ihrer jeweiligen Sportart führten verschiedene neuropsychologische Tests durch, die Arbeitsgedächtnis, Inhibitionsleistung, Verarbeitungsgeschwindigkeit und kognitive Flexibilität erfassen. Verwendet wurden dabei der Design Fluency Test, Trail Making Test, eine Flanker Aufgabe, und eine 2-back Aufgabe. Retrospektive Interviews erfassten früheres sportliches und musikalisches Engagement von Athleten/innen. Ihre Einbindung in verschiedene Sportart-Typen (statische-, dynamische-, und strategische Sportarten) wurde für die Analyse in Altersepisoden zusammengefasst.

Ergebnisse: Multiple Regressionen zeigten, dass Engagement in dynamischen Sportarten, insbesondere vor dem 13. Lebensjahr, und musikalisches Engagement EF Messergebnisse der kognitiven Umstellungsfähigkeit und Verarbeitungsgeschwindikeit signifikant vorhersagen konnten. Umfangreiches Engagement in statischen Sportarten beeinträchtige allerdings die Leistung der Verarbeitungsgeschwindikeit. Darüber hinaus zeigten die Rangkorrelationsanalysen nach Spearman, dass die Gesamtanzahl der verschiedenen Sportarten, welche ein/eine Athlet/in während seiner Karriere ausgeübt hatte, sowie der Ersteinstieg eines Sportlers oder einer Sportlerin in regelmäßigen Sport einen signifikanten Zusammenhang mit Messergebnissen der kognitiven Umstellungsfähigkeit und Verarbeitungsgeschwindikeit hatte.

Conclusio: Die Ergebnisse zeigen, dass EF von umfangreichem Training in bestimmten Sportart-Typen und Aktivitäten im Verlauf einer sportlichen Karriere beeinflusst werden. Dies unterstreicht die Notwendigkeit die Entwicklungsgeschichte von Athleten/ Athletinnen besser zu untersuchen um ein besseres Verständnis über die Bedeutung von EF im Sport zu erlangen.

Abstract

Objective: Recent research detected better performance on executive function (EF) measures in elite athletes competing in interceptive or strategic sports and provides a fertile soil for uncovering coherences between athletics and cognition. However, research is lacking to scrutinize how athletes' sport involvement or creative activities during childhood and youth contribute to the development of their EF.

Method: Fifty-seven Austrian elite-athletes (36male / 21female; age: 22.86 ±4.66 yrs.), competing at the highest national level in their respective sport, conducted different neuro-psychological tests measuring working memory, inhibition, perceptual speed and cognitive shifting. Design Fluency Test, Trail Making Test, Flanker task, and a 2-back task were used. Retrospective interviews assessed athletes' past sport and music involvement. Athletes' involvement in static, interceptive and strategic sports was clustered into age episodes for analysis.

Results: Multiple regression showed that interceptive sport involvement, especially before the age of 13, and music involvement significantly predicted EF measures of cognitive shifting and perceptual speed, whereas static sport involvement hindered performances on perceptual speed. In addition, Spearman's rank-correlation analyses indicated that the total number of different sports participated in during one's career and the age of an athlete when first entering regular sports significantly correlated with measures of cognitive shifting and perceptual speed.

Conclusion: The results demonstrate that EF measures were influenced by extensive practice in certain sport types and activities during an athlete's career, emphasizing the need to investigate the athletes' developmental histories for better understanding.

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1. Introduction

When studying relationships between the brain or mind and sport, past studies addressing the influence of cognitive abilities on athletic performance provide a fertile soil for gaining more insight into this complex matter. Most recent research has displayed the usefulness of physical activity and fitness training when trying to improve cognitive skills (Best, 2010; Diamond & Ling, 2016; Etnier & Chang, 2009; Kramer & Erickson, 2007; Marchetti et al., 2015). Improvement of cognitive skills through sport could also be supported by studies reporting that athletes outperform non-athletes or population norm in certain cognitive abilities (Abernethy, Baker, & Côté, 2005; Lundgren, Högman, Näslund, & Parling, 2016; Mann, Williams, Ward, & Janelle, 2007; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012; Vestberg, Reinebo, Maurex, Ingvar, & Petrovic, 2017; Voss, Kramer, Basak, Prakash, & Roberts, 2010). On the other hand, several studies also reported that cognitive abilities can determine athletic performance and can influence an individual's athletic progress (Cona et al., 2015; Faubert, 2013; Faubert & Sidebottom, 2012; Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Vestberg et al., 2012; Vestberg et al., 2017). Of further interest on this subject therefore is if certain cognitive abilities are shared between certain activities and can be carried over.

1.1. Cognitive skill transfer

A recent topic of cognitive adaptions to sport is the cognitive skill transfer hypothesis that suggests training a certain cognitive task enhances performance on related untrained cognitive task (Jacobson & Matthaeus, 2014; Taatgen, 2013; Voss et al., 2010; Wang et al., 2013). The extent to how "far" these cognitive skills can transfer is topic of a still ongoing research stream (Allen, Fioratou, & McGeorge, 2011; Furley & Memmert, 2011). Furley and Memmert (2011) contribute to this subject by further explaining the current discussion. The narrow transfer hypothesis states that participating in sports or playing an instrument over a prolonged period results in superior cognitive skills, related to the respective field, but does not transfer to cognitive abilities that are outside of that field (Furley & Memmert, 2011; Jacobson & Matthaeus, 2014). An example study for this narrow transfer displays that expert chess players possess greater working memory capacity of chess configurations but not greater working memory overall (Chase & Simon, 1973). The broad transfer hypothesis on the other hand states that extensive training in a certain domain, like action video gaming (Green, Pouget, & Bavelier, 2010) or certain team sports (Jacobson & Matthaeus, 2014; Voss et al., 2010), can result in beneficial cognitive adaptions that are present even outside of the trained context (Allen et al., 2011; Furley & Memmert, 2011). Empirical evidence therefore exists for both the narrow and the broad transfer hypothesis, but evidence is still inconclusive.

To assess cognitive abilities in the context of sports, studies used specific tests designed for a certain sport. One example used was the recall of domain-specific patterns, by showing snippets of netball, basketball and ice hockey video footage and after occluding the video asking the participants to recall and reproduce the positions of all players (Abernethy et al., 2005). While those sport specific cognitive tests can predict and distinguish between elite and novice players (Abernethy, 1989; Abernethy et al., 2005; Abernethy, Gill, Parks, & Packer, 2001), they discriminate athletes, competing in other sports then the one the test was designed for, since they require procedural and declarative knowledge of the sport situation (Voss et al., 2010). They also lack comparability to other cognitive tests (Vestberg et al., 2017; Voss et al., 2010). Some studies also did distinguish between elite athletes and novices by using general tests of cognition (Alves et al., 2013; Bianco, Di Russo, Perri, & Berchicci, 2017; Wang et al., 2013), whereas others lacked clear discrimination between elite and novice athletes (Memmert, Simons, & Grimme, 2009; Nakamoto & Mori, 2008). These findings reported under the umbrella term cognitive abilities needs to be further evaluated to clarify which specific ability is affected by which particular physical activity or sport. Recent studies assessed the cognitive concept of executive functions (EF) in the sports context, in order to detect relationships between general cognitive abilities and athletics (Ishihara, Sugasawa, Matsuda, & Mizuno, 2017; Jacobson & Matthaeus, 2014; Krenn, Finkenzeller, Würth, & Amesberger, 2018; Lundgren et al., 2016; Verburgh et al., 2014; Vestberg et al., 2012; Vestberg et al., 2017; Voss et al., 2010) showing promising results that can enhance inter sports comparability. Executive functions are a higher order construct that includes the abilities of attentional control, updating and monitoring of working memory, inhibition and interference control, and shifting or switching between tasks, operations or mental sets further termed as cognitive flexibility. Skills required in sports can translate to general cognitive domains that can be measured by EF assessments, thus making them comparable to all populations and age groups and furthermore can quantify and illustrate differences when it comes to cognitive abilities (Diamond, 2013; Furley & Memmert, 2011; Memmert et al., 2009; Vestberg et al., 2012; Vestberg et al., 2017; Voss et al., 2010).

1.2. Executive functions

Executive functions (EF) are cognitive processes that are necessary for cognitive behavior control. They select, monitor and control our behavior while including and processing the environment enabling us to think before we act, conquer and master difficult challenges that we have not experienced before, and help us stay focused in an environment of sensory overload (Diamond, 2013). Bearing this definition in mind, EF should support humans when performing sports, especially in competitive situations. The general agreed three core EF are working memory (WM), inhibition (INH), and cognitive flexibility (CF); (Baggetta & Alexander, 2016; Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). Their relationship to each other and related terms is explained below and further illustrated in Figure 1.

1.2.1. Working memory

Updating and monitoring of WM allows us to process and hold on to information and to further work with them mentally, dynamically manipulating the information rather than passively storing it (Diamond, 2013; Miyake et al., 2000). Updating the working memory requires individuals to code and select information relevant to the task and replacing previous and no longer necessary information with new and more relevant information (Miyake et al., 2000). WM can be distinguished by two types, verbal and nonverbal (or visual-spatial) working memory. WM is the foundation of most other EF constructs as it helps us making sense of things that otherwise would be unrelated to another and brings conceptual knowledge to our decisions. To make those decisions and plans we need to remember the past in perspective of future hopes, disassemble and recombine elements and thoughts in new ways. (Diamond, 2013; Miyake et al., 2000). An important use of working memory during sports with only one opponent like combat or racket sports would be to memorize previous moves, tendencies and tactical approaches of your opponent in order to anticipate and react faster if that same situation occurs again.

1.2.2. Inhibition

Inhibition or interference/inhibitory control enables us to screen and select our emotions, thoughts, memories, and behaviors to override or resist internal impulses and instead react in a socially acceptable and appropriate way (Diamond, 2013; Lehto et al., 2003). Without INH, we would rely on impulse, habit, or environmental stimuli to manifest our actions or thoughts. Another aspect of INH is self-control, which enables individuals to control their emotions and behavior. Resisting the interference of a distractor, INH of attention, and resisting a prepotent response, INH of action, furthermore are different aspects of inhibitory control but are strongly correlated to another according to results from factor analyses (Friedman et al., 2006). Voluntary resisting irrelevant or unwanted thoughts or memories, like intentional forgetting or resisting interferences from information, is called cognitive inhibition and needs support from WM. In situations where the initial tendency to perform an action needs to be countered by the information acquired earlier, WM and INH work closely together and support each other (Diamond, 2013). By exercising all aspects of INH, we can have the possibility of change and choice and can focus on specific tasks and suppress certain stimuli. INH also supports WM by suppressing irrelevant information that would otherwise congest our mental workspace and helps us focus on what we really want to remember (Diamond, 2013). It is most visible in sports when athletes need to perform well in crucial game deciding actions and therefore must block out stadium noise, distractive movements from the opponent, or their own destructive thoughts.

1.2.3. Perceptual speed

Another factor that was often reported in studies assessing EF was perceptual speed or also termed processing speed (e.g.Voss et al., 2010; Yongtawee & Woo, 2017). Perceptual speed refers to the ability to perceive visual details, like letters, numbers, objects, pictures, or patterns fast and accurately and is a factor of intelligence in the multiple factor theory (Thurstone, 1938).

1.2.4. Cognitive flexibility

Both INH and WM are the foundation of CF, which is developed later in an individual's life than the other two EF (Best, Miller, & Jones, 2009; Diamond, 2013). CF is the ability to change perspectives spatially or interpersonally, to think outside the box or deliberately switching your center of attention (Diamond, 2013). Switching back and forth between different tasks by disengaging the previous now irrelevant task and the subsequent active engagement of the new now relevant task often results in inferior performance of each individual task (Kiesel et al., 2010; Miyake et al., 2000). The term switch cost refers to this difference between the performance of a task A followed by the same task, and the performance of a task A followed by the task B (Kiesel et al., 2010). Therefore, task switching could be viewed as an ability that taps into the construct of CF. Consequently the CF construct can implicate and overlap with task switching, set shifting, and creativity (Diamond, 2013; Ionescu, 2012; Kiesel et al., 2010; Miyake et al., 2000). The creative process of CF is enhanced through evaluating the appropriateness of a novel insight, activating executive processes relevant to the task and by implementing goal-oriented expression of the insight (Dietrich, 2004). By inhibiting or suppressing our point of view of previous acquired information or behavior and transfer a new perspective into our WM we can change our way of thinking. This illustrates how CF builds on, and requires INH and WM. In this way we can change our demands and priorities when things do not go as planned, be flexible in our thinking, and come up with new ideas and solutions (Diamond, 2013). The ability of an athlete to adjust to their opponents in a fast and flexible way and come up with new movements, maneuvers, or tactical approaches is often an important trait in most sports, thus showing the significance of CF.

1.2.5. Higher level executive functions

All three core EF are top-down processes that contribute to goal directed behavior, reasoning, problem-solving, and planning which are termed as higher-level EF (Diamond, 2013; Miyake et al., 2000). The demand of the task is what distinguishes core EF and higher-level EF (Luciana, Conklin, Hooper, & Yarger, 2005), which means more complex cognitive tasks, like maintaining and manipulating information to strategically organize goal oriented behavior, are more related to higher-level EF (Luciana et al., 2005). Fluid intelligence is synonymous with reasoning and problem-solving and includes inductive and deductive reasoning (Diamond, 2013). Fluid intelligence enables us to solve problems and see patterns or relationships among items, figure out abstract relations and solve novel problems independent from the past (Ferrer, O'Hare, & Bunge, 2009). Planning refers to the process of creating, organizing and maintaining a plan to achieve a desired goal (Owen, 1997).

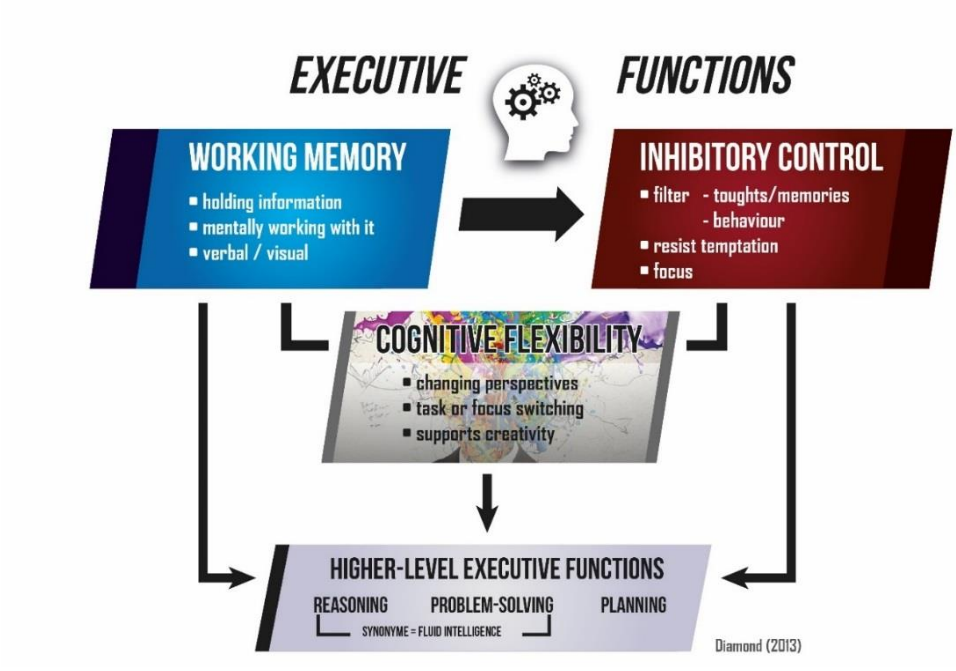

Figure 1: Executive Functions relationship and related terms adapted from Diamond (2013)

In order to solve a sport specific problem using logical reasoning or generate an action plan for a sport situation we rely on core EF to contribute to these higher-level EFs. For example by deciding to use a specific approach on how to attack your opponent in judo and therefore winning a tournament (higher-level EF – goal directed planning), working memory is required to hold this tactical approach in mind and continuously update this tactic with information acquired during the fight, with inhibition contributing further by not losing focus due to exhaustion, audience noise or distractors which are irrelevant for the upcoming task. In this example cognitive flexibility helps to change the approach if the tactic does not work out like it was supposed to be. Particular in team sports like soccer, basketball, football, or rugby, athletes need to quickly adapt to constant environment changes around them, change strategy and inhibit responses, hence core EF and higher-level EF, like problem solving or task switching seem most important (Stratton, 2004).

1.3. Excutive functions in the context of sports

For a better understanding of cognitive abilities transfer, we need to consider the influence of sports on EF and likewise the influence of EF on sports performance. In light of the applicability of EF to sports, research detected significant higher EF scores of elite athletes when compared to non-athletes (Alves et al., 2013; Bianco et al., 2017; Lundgren et al., 2016) and Elite athletes outperformed sub-elite athletes in soccer (Vestberg et al., 2012), youth soccer (Huijgen et al., 2015; Verburgh et al., 2014; Vestberg et al., 2017), judo (Supinski, Obminski, Kubacki, Kosa, & Moska, 2014), and ultra-marathon (Cona et al., 2015) on certain EF measurements. Furthermore, correlations where found between on-ice performance and EF scores in Swedish ice-hockey players (Lundgren et al., 2016). Vestberg et al. (2012; 2017) could furthermore predict athletic performance by measuring EF in Swedish elite soccer players prior to the season, and found correlations between goals/assists and performance of WM and CF. Clear distinction based on EF between elite and amateur athletes in all sports must be applied with caution since detection of different expertise levels by measuring EF failed to reach statistical difference in basketball (Nakamoto & Mori, 2008), fencing (J. S. Chan, Wong, Liu, Yu, & Yan, 2011), tennis (Kida, Oda, & Matsumura, 2005) and ice hockey (Lundgren et al., 2016) for example. Also, effects were only significant for certain sub constructs or aspects of EF and not for others (Alves et al., 2013; Huijgen et al., 2015; Verburgh et al., 2014). The label “elite athlete” often is hard to standardize, since competition levels can vary drastically between sports and even within the same sport. Under this label elite alpine skiers from Austria who regularly finish in the top 10 would be compared with elite alpine skiers from Bolivia for example who would finish last in most competitions. Furthermore, the number of competitors in a certain sport is also crucial factor when looking at elite athletes. Soccer for example is played all over the world, thus reaching the highest level of competition places great demands on an athletes physical and cognitive skills, whereas reaching elite status in minority sports like polo or natural track luge would be more likely than for soccer players. The differing categorization of when athletes can be termed as elite or expert and the different measurement tools used to assess EF provide a challenge for comparing results. With this in mind, careful considerations should be placed on selecting or assessing elite status and comparison to non-elites. A suggestion therefore would be that future research should emphasize to report and clarify the level of competition and expertise of those athletes. Considering the current research with all its limitations, it was still hypothesized that differences in EF would be better detectable in athletes with high expertise in their respective sport.

1.4. Influence of specific sport types on EF

Most recent studies further illuminate the influence of different sports on EF and provide information regarding the broad skill transfer hypothesis (Jacobson & Matthaeus, 2014; Krenn et al., 2018; Voss et al., 2010). Through extensive and repeated engagement in certain athletic activities, the varying cognitive demands of different sports could become visible when assessing EF. To illustrate these different cognitive demands Singer (2000) classified sports either as self-paced or externally paced. Sports or behavior that allow the athlete to prepare themselves for critical actions and take their time to perform it, like bowling, running, or swimming are self-paced also termed static sports. Sports that require quick decision making with changing external environment like volleyball, or soccer, are classified as external-paced. To better match the ecological validity of cognitive demands in sport, external-paced sports was then further divided into interceptive sports, like racquet sports, and strategic sports, such as team sports with multiple teammates, opponents, and tactical variants (Singer, 2000). Interceptive sports require constant coordination between parts of the body and an implement or object in the environment (Davids, Savelsbergh, & Bennet, 2004; Voss et al., 2010), whereas strategic sports require simultaneous processing of vast information regarding teammates, opponents, field position and sports object (Voss et al., 2010).

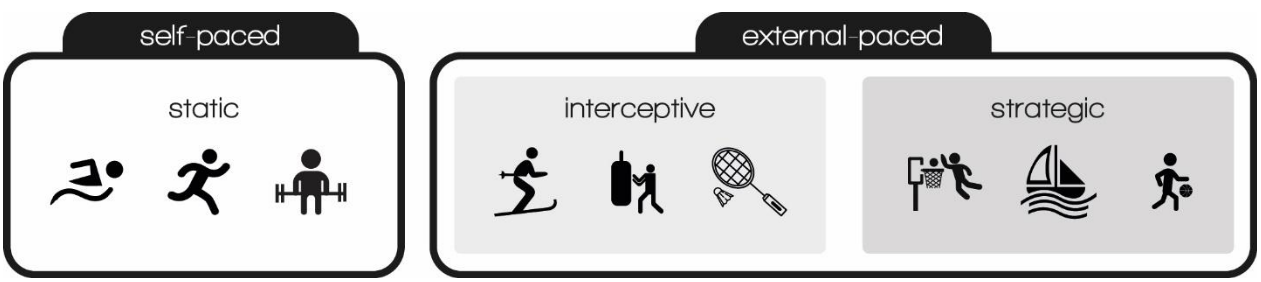

Figure 2: Classification of self- and external-paced sports

In this regard, Jacobson and Matthaeus (2014) reported that external paced athletes did outperform self-paced athletes in terms of problem solving but had lower scores than self-paced athletes on an inhibition task. In contrast, varsity tennis players, who are classified as external paced, did better on inhibition control compared to closed skill sports, like swimming (Wang et al., 2013). Kida et al. (2005) found no differences in simple reaction times when comparing baseball players, tennis players and non-athletes, and when comparing professional and varsity baseball players, but did detect faster reaction times only for the baseball players during a Go/No-go task, which requires a response for a certain stimuli (go) and inhibit this response on a different stimuli (no-go). Bianco et al. (2017) also found faster reaction times during the Go/No-go task, comparing boxers and fencers with non-athletes. Additionally, varsity badminton players performed better in both proactive and reactive controls for task switching than varsity track and field athletes but still, badminton and track and field athletes outperformed the control group that never played any sport games professionally or at an amateur level (Yu, Chan, Chau, & Fu, 2017). These findings were furthermore supported by Nakamoto and Mori (2008) who reported shorter reaction times of basketball and baseball players during a simple reaction task and a Go/No-go task, when compared to non-athletes. Go/No-go reaction times varied significantly across experience for the baseball players. Faster reaction times were linked to increased training experience in interceptive sports, mainly combat sport athletes, if compared to static sports (Yongtawee & Woo, 2017). Longer tennis experience was also related to better processing speed and EF (Ishihara et al., 2017) as was longer judo experience related to better cognitive performance using a go/no go task and a visual motor coordination task (Supinski et al., 2014). Krenn et al. (2018) examined Austrian elite athletes and furthermore revealed benefits of strategic sports, when compared to static sports, in mean reaction times, cognitive shifting, and working memory. A meta-analytic review confirmed that external-paced athletes also possessed superior processing speed when compared to self-paced athletes, with interceptive athletes showing the largest statistical significance (Voss et al., 2010). This evidence summed up in Table 1 indicates that external paced sports, especially interceptive sports like tennis or combat sports, demand higher cognitive skills and nurture those skills by prolonged involvement, furthermore emphasizing that sport type and the length of sport participation both influence EF and cognitive abilities.

Table 1: Summary of effects discovered in studies assessing cognitive abilities, sport type and length of sport participation

Study	*Experts > Novices (1)*	*Experience effect (2)*	*Interceptive effect (3)*	*Strategic effect (4)*
Bianco et al. (2017)	+			
Ishihara et al. (2017)		+		
Jacobson and Matthaeus (2014)			+/-	+/-
Kida et al. (2005)	-		+	
Krenn et al. (2018)				+
Nakamoto and Mori (2008)	+	+		
Supinski et al. (2014)		+		
Voss et al. (2010)			+	+
Wang et al. (2013)			+	
Yongtawee and Woo (2017)		+	+	
Yu et al. (2017)	+		+	

Note: (1) Experts outperform Novices on executive functions, (2) more experience linked to better executive functioning, (3) Interceptive sports outperform other sports on executive functions, (3) Strategic sports outperform other sports on executive functions.

The summed-up evidence illustrates a trend favoring external-paced over self-paced sports when it comes to EF, up to my current knowledge, studies fail to scrutinize how athletes' sport involvement or more broad concepts like creative activities during childhood and youth contribute to the development of their EF. Supplemental assessment of sport involvement would further enable researchers to gain insights into the socialization vs selection effect of certain sport types. Developing cognitive skills through the extensive time spent with particular sports would be viewed as a socialization effect (Voss et al., 2010). The selection effect hypothesizes that certain cognitive skills are a prerequisite to excel and stay engaged in certain sports (Voss et al., 2010). Athletes with a less useful skill set would therefore drop out of that sport more likely. This leads to the assumption that the cognitive skills that can be observed when assessing sport types is only the effect of the sport filtering out most athletes with unbeneficial skill sets. Both effects would not be visible when assigning athletes to a certain sport type cluster by taking a snap-shot approach, only considering the main sport in which they currently compete. This could be prone to missing out on valuable influences and transfer effects from other sports and activities that shape their EF. Keeping in mind, that expert or elite athletes from a certain sport type should have considerably invested training in their respective sports, there are still uncertainties about the accuracy of this assumptions. An example to illustrate this dilemma could be biathlon, where athletes need to finish a cross country ski race with episodes of target rifle shooting in between the race. Elite biathletes could have invested numerous hours in cross country skiing only, then learned to shoot a rifle in a considerable small amount of time and still would outrace their opponents even if they underperform on the target shooting. Also, elite biathletes who are world class target shooters with little cross-country skiing experience could still win races because of their superior shooting performance. Both would be classified under the term biathlon athlete without considering their sport trajectories. It could be further hypothesized that their EF differ in certain aspects. This is further supported by studies from Baker, Côté, and Abernethy (2003) reporting that reaching expert performance with limited sport specific training was associated with engagement during childhood in numerous sport activities and vice versa. Meaning that athletes with a great number of athletic activities required less domain-specific practice to acquire expertise within their main sport (Baker et al., 2003; Côté, Baker, & Abernethy, 2003). A study from Abernethy et al. (2005) reported that expert athletes from netball, basketball and field hockey outperformed experienced but non-expert players during a recall task for patterns of play derived from each of these sports. Experts did outperform non-experts on pattern recall tasks different from their main sport, in addition to superior performance over non-experts in their own respective sport. Subsequently, experts in sports are able to transfer those cognitive abilities to other sports, enabling them to outperform other novice players in that sport (Abernethy et al., 2005; Williams, Ford, Eccles, & Ward, 2011) but how those skills transfer between sports is still not clear (Williams & Ford, 2008). Assessing the history of athletes might enable future researchers to provide better insights into transfer effects between different sport types. It could also answer questions about the influence of socialization effect, development of certain EF constructs through investment in specific sports, versus selection effect, indicating that only individuals with certain preexisting EF performance excel in that sport (Voss et al., 2010). Hypothetical both the socialization effect and the selection effect are present in an ecological context.

To look further into this matter, repeated engagement or practice, challenging tasks and intrinsic motivation seem necessary to develop expert level, this links also to the development of executive functions (Diamond, 2013) which occurs throughout childhood and continues until young adulthood (Best et al., 2009). Being involved in several sports and therefore facing more cognitive challenges in multiple settings, could enhance improvement in EF. More sport rules, strategies, or techniques need to be remembered and updated in the WM. Temptation to kick the ball with the foot in a volleyball game, when you previously played more soccer, must be suppressed indicating improvements in INH. Switching from one sport to another and employing different tactics, movements and complex tasks to be successful would require involvement of CF and higher-level EF. Further insights into causation of sport involvement on cognitive abilities can be gained by looking at cognitive development.

1.5. Tracing the developmental path of athletes

The theory of cognitive development by Piaget (1970) defines 4 different stages how humans gradually acquire, construct and use knowledge over their development. The sensomotoric stage lasts from birth until age 2 where infants construct knowledge by coordinating their physical environment with their coordination experience, like vision and hearing (Piaget, 1970; Santrock, 2004; Tuckman & Monetti, 2010). During the preoperational stage, which lasts from age 2 until 6 or 7, children are able to form concepts, can think in images or symbols, and start reasoning but still lack the ability to switch perspective or to manipulate and transform information in a logic way (Piaget, 1970; Santrock, 2004; Tuckman & Monetti, 2010). From 6 or 7 years until age 12 or 13 the concrete operational stage is characterized by the use of logic, problem solving abilities, understanding rules and inductive reasoning but lack deductive reasoning (Piaget, 1970; Santrock, 2004; Tuckman & Monetti, 2010). The Formal operational stage lasts from around age 12 until approximately age 15 to 20 and enables individuals to think in abstract concepts and perform hypothetical and deductive reasoning (Piaget, 1970; Santrock, 2004; Tuckman & Monetti, 2010). This highlights that an athletes' future cognitive development might be enhanced by involvement in certain activities during these different stages.

By tracing the developmental path of athletes, retrospective interviews can help us with valid information to gain insights in the type of sport, practice, and contextual environments they have experienced (Côté, Ericsson, & Law, 2005). Studies that investigated expert performance showed that practice hours in their respective sport was not always a reliable predictor of success (Baker et al., 2003; Hornig, Aust, & Güllich, 2016). Factors additional to the sport specific training like involvement in creative, artistic or sporting leisure play, influenced their expertise attainment (Baker et al., 2003; Côté, Baker, & Abernethy, 2007; Côté et al., 2005; Hornig et al., 2016).

In their repeated effort of investigating elite Australian and Canadian athletes Côté and colleagues distinguish between three different stages that athletes go through to reach expert performance (Abernethy, Côté, & Baker, 1999; Côté, 1999; Côté et al., 2003, 2007; Côté & Hay, 2002). The sampling years ranging from about age 5 to 12 of an athlete were characterized by first contact with sports and regular sport activities, giving athletes the chance to experience multiple sports to develop fundamental motor skills (Côté & Hay, 2002). During the specializing years between approximately age 13 to 15, athletes focused on one or two sports and sport specific skill acquisition (Côté & Hay, 2002). Past age 16, athletes then entered the last stage, which was divided into two different pathways. Elite athletes heavily invested in their respective main sport, therefore called the investment years, whereas other athletes still participated in regular sports but did not reach elite performance levels during their so-called recreational years (Côté & Hay, 2002).

The developmental model of sport participation (Côté, 1999; Côté, Lidor, & Hackfort, 2009; Côté & Vierimaa, 2014) is a model of athlete development centered around seven postulates, describes the processes, pathways and possible outcomes of sport development through childhood and adolescence. In the latest update of the model Côté and Vierimaa (2014) stated that a diverse sport involvement during childhood and youth enhances foundational skills needed for recreational sport options later in life and promotes long-term sports engagement. Early specialization in only one sport on the other hand, can lead to higher dropout rates and an increased risk of injuries, due to monotone and higher training loads at a young age, furthermore shortening an athletes' career (Côté et al., 2009). Particularly during childhood and youth, diverse sport involvement and deliberate play, a term that refers to mostly unorganized time dedicated for enjoying activities rather than deliberately practicing them, can also foster a wide range of motor and cognitive experiences and build better intrinsic motivation (Côté et al., 2009; Côté & Vierimaa, 2014; Ericsson, 2006; Rees et al., 2016). During leisure or deliberate play, athletes can acquire much more actual physical activity and learning experiences than in any kind of structured practice. This indicates the importance of participating in several activities apart from the main sport to reach elite level. Elite athletes in sports, like ice hockey, soccer, baseball, triathlon or rowing, that reach peak performance after they have fully matured, which is generally between 25-35, can start to specialize and invest heavily in their respective sport at age 13-16 (Côté et al., 2009; Côté & Vierimaa, 2014) and can use their childhood to participate in leisure activities and deliberate play. This was evident also in German elite soccer players, who spent more time in non-organized leisure football play than organized practice/training until age 14 (Hornig et al., 2016). After that age leisure activities of those soccer players declined, and organized practice increased, underlining the claim that late adolescents (~16years) possess the requirements, physical, cognitive, social emotional and motor skills, to participate in specialized training (Côté et al., 2009). Other sports like gymnastics and figure skating reach elite levels often before full maturation of the athlete, therefore early specialization is a strong predictor of elite performance in these sports although research has indicated various negative outcomes associated with this early specialization (Côté & Vierimaa, 2014).

Up to my current knowledge especially more broad activities unrelated to sports have not been studied extensively in the context of sport. Creative activities like participating in a theater play, playing an instrument, dancing, or painting have the potential to improve cognitive abilities and EF through repeated effort, extended practice, and commitment to push yourself by providing joy, building self-confidence, creating belonging to a group and challenging your body (Diamond & Ling, 2016). Evidence is provided by a study showing that short term training of music elements improved EF assessed through a Go/no-go task in preschool children when compared to visual art training (Moreno et al., 2011). Additional studies showed that duration of music lessons and training were also significantly related to inhibition (Bialystok & DePape, 2009; Degé, Kubicek, & Schwarzer, 2011) set shifting (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Degé et al., 2011), selective attention, planning, and fluency (Degé et al., 2011). Degé et al. (2011) furthermore indicated that executive functions, in particular selective attention and inhibition mediate the relationship between music involvement and intelligence. In this regard, interesting studies showed differences in cognitive flexibility between individuals with videogame experience and individuals with almost no videogame experience (Colzato, Van Leeuwen, Van Den Wildenberg, & Hommel, 2010) and acute improvement of cognitive flexibility following a video-game training (Glass, Maddox, & Love, 2013).

These findings support the possibility of broad transfers between high-level cognitive activities. It was hypothesized that prolonged involvement in leisure sports, competitive sports, and creative activities would greatly influence EF and hence was assessed using the proposed retrospective approach.

2. Methods

2.1. Ethics statement

The study was approved by the university of Vienna ethics committee, process number 00253. All participants received written and verbal information about the study and the purpose of the thesis and had to give written and verbal consent in order to participate. All psychological tests and interviews were conducted by trained scientists and supervised by Mag. Dr. Björn Krenn.

2.2. Participants

Fifty-seven Austrian elite athletes (36 male / 21 female; age: 22.86 ± 4.66yrs.) from different sports participated in this present study. To ensure elite status of participants, athletes were only included if they were either part of the active national team or competed in the highest Austrian league in their respective sport during the year 2018. Athletes were excluded if they had injuries or impairments of hands and eyes that limited or prevented them to perform the tests. They were also excluded if they had preceding brain injuries or concussions that occurred less than two weeks before the assessment. Concentrated effort was made to recruit groups of static, interceptive and strategic athletes with extensive training experience, which should be assumed in athletes competing at the highest national level.

Following the taxonomy of grouping different sports (Singer, 2000; Voss et al., 2010) sports like running, swimming, cycling, were defined as static since they involve highly consistent, self-paced situations (Singer, 2000; Voss et al., 2010). Sports that require constant coordination between parts of the body and an implement or object in the environment, were defined as interceptive (Davids et al., 2004; Voss et al., 2010), hence sports like alpine skiing, judo, tennis, were classified as interceptive. Strategic sports require simultaneous processing of vast information regarding teammates, opponents, field position and sports object. Volleyball, basketball, sailing or soccer were classified as strategic respectively (Voss et al., 2010). In the current sample 17 athletes (9 male / 8 female) from sport shooting and swimming were assigned to static sports, 8 athletes (2 male / 6 female) from canoe slalom were assigned to interceptive sports and 32 athletes (25 male / 7 female) from sailing, basketball and American football were classified as strategic sports. To disclose the competition level of the current sample several factors are reported below. Swimmers all competed internationally, participated in 12 European championships, 1 world championship, and accumulated an average of 1.28 years at their highest level of competition. Two canoe slalom athletes were regarded as top 10 of the world while the other 6 competed internationally, participated in a combined 13 European championships, 11 world championships, and accumulated an average of 2.25 years at their highest level of competition. Eight athletes from sport shooting were regarded as top 10 of the world while one competed internationally, participated in a combined 49 European championships, 15 world championships, 4 Olympic games, and accumulated an average of 1.66 years at their highest level of competition. Basketball players were vice champions of Austria during the season 2018 with 1 player competing in a top 10 league of the world, 2 competed internationally, 8 competed on a national level, and accumulated an average of 3.27 years at their highest level of competition. American football players finished the 2018 season as vice champions of Austria, with 8 athletes competing internationally, 2 competing on a national level, participated in 5 European championships, and accumulated an average of 1.90 years at their highest level of competition. Eight athletes from sailing were regarded as top 10 of the world while 4 competed internationally, participated in a combined 56 European championships, 59 world championships, 2 Olympic games, and accumulated an average of 3.16 years at their highest level of competition.

2.3. Materials

For assessing executive functioning a test battery was designed, consisting six different neuro-psychological tests, to cover the diversity of constructs with focus on the three core EF, working memory, inhibition and cognitive flexibility. The Design Fluency and Trail Making subtests from the D-KEFS test battery, a modified Eriksen flanker task and a complex version of the flanker task, a 2-back task, and an explorative sorting task were used.

2.3.1. Design Fluency Test

During the Design Fluency test (DF) the participants are asked to connect dots, which are framed in a square, with four lines using a pen. Three Conditions need to be completed by the participant

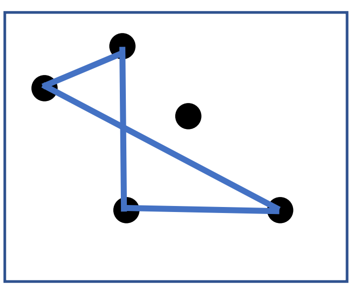

Figure 5: Exemplary adaption of the D-KEFS Design fluency test Condition 1 (Delis, Kaplan, & Kramer, 2001) – Participants are asked to draw four lines, connecting the filled dots to create designs.

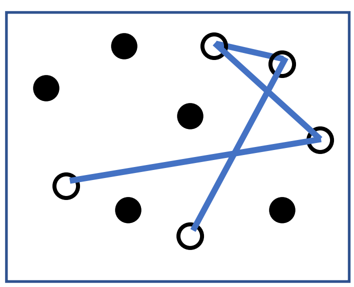

Figure 5: Exemplary adaption of the D-KEFS Design fluency test Condition 2 (Delis, Kaplan, & Kramer, 2001) – Participants are asked to draw four lines, connecting the empty dots to create designs.

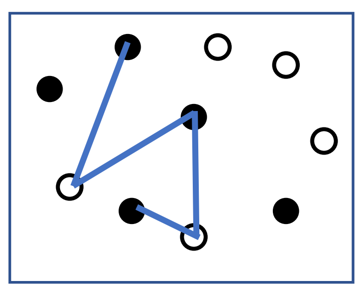

Figure 5: Exemplary adaption of the D-KEFS Design fluency test Condition 3 (Delis, Kaplan, & Kramer, 2001) – Participants are asked to draw four lines and alternate between a filled an empty dot to create designs.

under time pressure, 60sec per condition, with the goal to create as many new different combinations or designs as possible. The participant is not allowed to draw fewer lines or to repeat a design – otherwise it is counted as an error. In Condition 1 (see Figure 5), the participant is asked to draw four lines, connecting the filled dots to create designs. In Condition 2 (see Figure 5), it is required to do the same but only by using the empty dots. In Condition 3 (see Figure 5), equal conditions apply regarding the design, but the participant must alternate between a filled an empty dot so one line connects one empty and one filled dot. Remembering the previous drawn designs and avoid repeating those designs, places great demands on working memory and inhibition skills (Delis et al., 2001; Vestberg et al., 2012). The participants need to find new solutions to achieve the goal. The third condition demands high cognitive flexibility to adjust to the new rule. Condition 3 is by far the most difficult one for the participants and prone to mistakes. The DF test is a nonverbal psychomotor test that measures test creativity, response inhibition and cognitive flexibility (Delis et al., 2001; Homack, Lee, & Riccio, 2005; Swanson, 2005) and was used previously in the sports context (Huijgen et al., 2015; Lundgren et al., 2016; Vestberg et al., 2012; Vestberg et al., 2017). Following executive functions are tapped by the test: initiation of problem-solving behavior, creativity in drawing new designs, fluency in generating visual patterns, simultaneous processing in drawing the designs while observing the rules and restrictions of the task, and inhibiting previously drawn responses (Delis et al., 2001). As a main metric the total number of correct designs drawn over all 3 conditions was used, listed as Design Fluency Total Correct in the manual (Delis et al., 2001).

2.3.2. Trail making test

Three subtests from the D-KEFS Trail Making Test (TMT) were used, condition 2 number sequencing, condition 3 letter sequencing and condition 4 number-letter switching. Condition 4 of the TMT requires the participant to switch back and forth between connecting circles, containing numbers and letters, in sequence and is the primary measure of executive functioning in this subtest (Delis et al., 2001). Using a pen, the examinee needs to connect numbers ascending and letters alphabetical with a line on the test document as quickly as possible, always alternating between a number and a letter. Condition 2 measures basic numerical processing, while condition 3 measures alphabetical sequencing (Delis et al., 2001). Both conditions require visual scanning, attentional abilities and motor functions (Delis et al., 2001). Condition 2 and 3 will help determining whether a deficiency in number-letter switching is related to a deficit in cognitive flexibility or to deficits in number sequencing or letter sequencing. Fluid intelligence and visual processing speed are the main cognitive abilities required (Salthouse, 2011). The number-letter switching subtest of the TMT (condition 4 see Figure 6) is designed to measure cognitive flexibility, visual scanning, and split attention (Delis et al., 2001; Lezak, Howieson, & Loring, 2012; Swanson, 2005) and previously was studied within the context of sports (Huijgen et al., 2015; Lundgren et al., 2016; Vestberg et al., 2012). The time of completion for each condition was used for analysis.

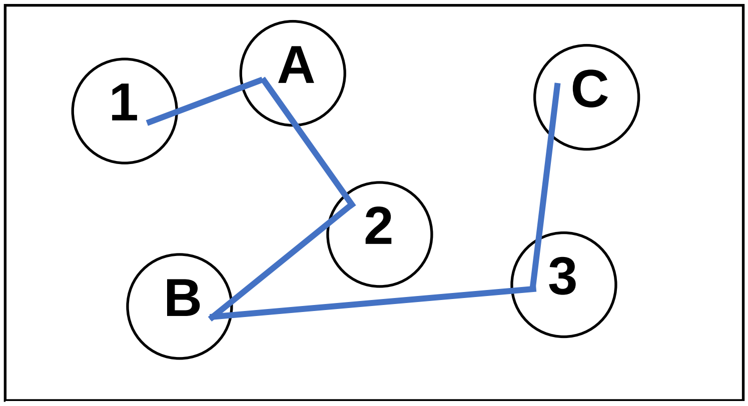

Figure 6: Exemplary adaption of Condition 4 D-KEFS Trail Making Test (Delis, Kaplan, & Kramer, 2001). Participants are asked to switch back and forth between connecting circles, containing numbers and letters, in sequence.

2.3.3. Flanker test

The modified Eriksen flanker task (FT) that measures response inhibition and visual attention (B. A. Eriksen & Eriksen, 1974; C. W. Eriksen, 1995; Krenn et al., 2018) includes 108 images that display five white arrows on a black screen. Participants were asked to use a computer and press the C key with their forefinger on the left hand if the arrow in the middle was directed to the left and press the M key if the arrow in the middle was directed to the right. They were required to react as quickly and accurately as possible. On 72 of those images, congruent stimuli, all arrows pointing in the same direction, were used. On 36 of those images, incongruent stimuli were used, with the middle arrow pointing in one direction and all other 4 arrows pointing in a different direction (Krenn et al., 2018). The flanking arrows have to be ignored or inhibited by the participants and require more inhibitory control then congruent stimuli (Diamond, 2013; B. A. Eriksen & Eriksen, 1974). A fixation cross was displayed at the location where the middle arrow would appear during the inter-trial interval. The inter-trial interval duration was randomized (500, 750, or 1000ms) and counterbalanced. All stimuli were displayed for 1000ms. Examples of stimuli shown during the test are shown in Figure 7. The main metrics used for analysis were the difference between mean reaction time (RT) of correct decisions on congruent and mean RT of correct decisions on incongruent stimuli.

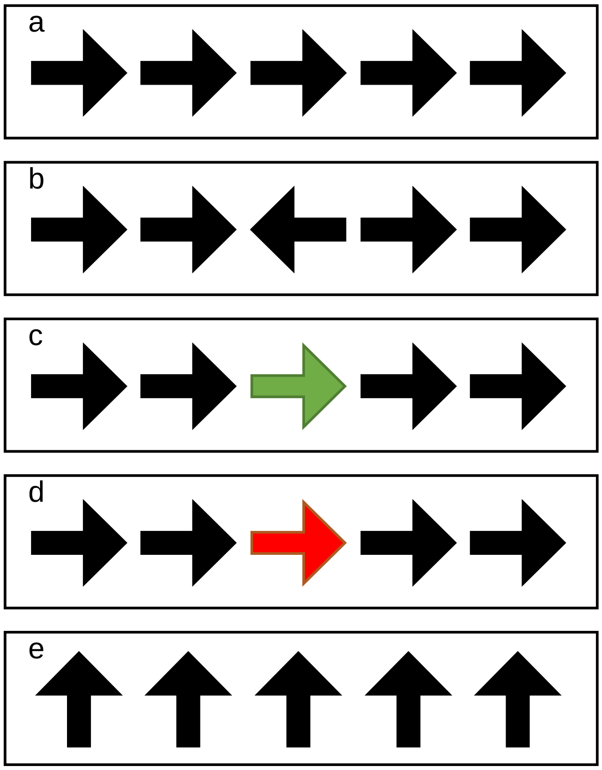

Figure 7: Stimuli of the modified Flanker task. A) congruent stimuli (correct response right), B) incongruent stimuli (correct response left); C) congruent stimuli in green (correct response right), D) incongruent stimuli in red (correct response left); E) Neutral stimuli (no response required)

Furthermore a more complex version of the FT was used to assess cognitive shifting (Krenn et al., 2018). The shifting task of the Flanker test (Flanker test shifting - FTS) consisted of additional stimuli. The task to respond quickly to the arrow in the middle was equal with the FT, 18 congruent stimuli and 18 incongruent stimuli where shown. Though, if the arrow in the middle was red (k=18), participants had to respond with the opposite key. When the arrow in the middle was shown in green (k=18), participants had to follow the same rules as if the arrow was white. Left and right arrow distribution in the test of was equal for both red and green arrows and only congruent stimuli, arrows all pointed in the same direction, were used. Participants therefore had to switch their response in accordance to the predetermined rules (Diamond, 2013; Yu et al., 2017). In addition, 36 neutral stimuli were used, displaying a middle arrow that pointed up or down. No reaction was required if this neutral stimulus was present. These different reactions that were implemented, responding in the same or the opposite direction of the arrow, or not responding at all, enhanced cognitive demands of the task and added additional shifting elements (Krenn et al., 2018). Examples of red, green and neutral stimuli are shown in Figure 7. Equal to the FT, 108 stimuli were displayed for 1000ms with inter-trial interval being randomized for 500, 750, or 1000ms. To analyze the high demands on shifting (Kiesel et al., 2010), attention was directed towards stimuli showing red arrows. The main metrics used for the FTS were errors on stimuli showing red arrows, mean RT for stimuli showing red arrows, and RT difference of red arrows and congruent stimuli.

2.3.4. 2-back test

During the 2-back task, participants were shown three conditions; dots on a dice, numbers, and geometrical forms on a computer screen, and had to press the space-bar if the current image was identical with the image that was already presented two stimuli earlier. Each condition contained six different stimuli (e.g. 1,2,3,4,5) that were presented in a fixed order. 48 stimuli for every condition, in total 144 were presented, and 8 times, in total 24, a stimulus matched the stimulus that was presented two stimuli earlier, thus requiring a response from the participant. Example stimuli are presented in Figure 8. Stimuli were presented for 1000ms in white on a black background, with inter-trial interval set to 500ms (Krenn et al., 2018). The 2-back test requires on-line monitoring, updating and manipulation of remembered information, which places great demand on working memory and working memory capacity (R. C. Chan, Shum, Toulopoulou, & Chen, 2008; Owen, McMillan, Laird, & Bullmore, 2005). Several studies analyzed it within the context of sport (Cona et al., 2015; Ishihara et al., 2017; Krenn et al., 2018). For further analysis, number of correct and false responses of all three conditions were used.

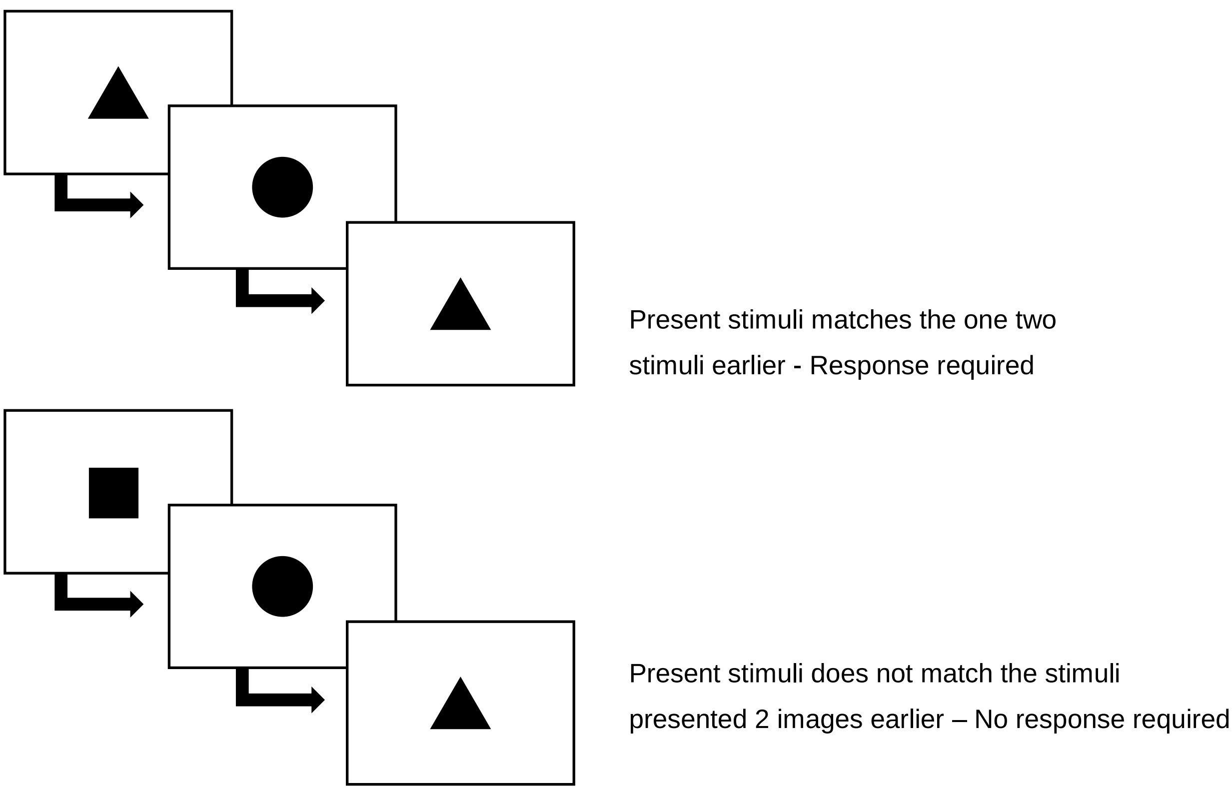

Figure 8: Example of the 2-back task

2.3.5. Computerized explorative sorting test (CEST)

The Wisconsin Card Sorting Test is one of the most popular tests used in clinical settings to measure EF and cognitive flexibility (Etnier & Chang, 2009). Delis et al. (2001) developed their own sorting task with 16 different conceptual sorting rules, compared to only three sorting rules used by the Wisconsin Card Sorting Test, and an alternate card set in order to limit practice effects (Homack et al., 2005). Evidence of moderate correlations between the Wisconsin Card Sorting Test and the D-KEFS sorting test were found (Delis et al., 2001; Delis, Kramer, Kaplan, & Holdnack, 2004). Both of the tests, were designed for clinical population and to detect deficits in EF. As stated in their manual (Delis et al., 2001), the D-KEFS sorting test provides measures of verbal and nonverbal problem-solving skills, the ability to explain sorting concepts abstractly, and inhibition of previous sorting and description responses in order to engage in flexibility of behavior and thinking. After careful consideration, a review of the provided tests, and to gain further insights into aspects of cognitive flexibility, a computerized explorative sorting test (CEST) was designed that was adapted from the D-KEFS sorting test and modified to be more complex in order to eliminate possible test-retest discriminations.

The CEST consisted of two conditions: the free sorting phase (FSP) and the sort recognition phase (SRP). During the FSP the participant was presented with 8 stimuli cards, showing stimulus words and various perceptual features. The participant was then asked to imaginary sort the stimuli cards into two groups, exactly 4 cards per group, remember the identification number displayed next to the card, and then press the space bar. On the next slide, it was required to mark the checkbox to identify the two groups that were chosen and to describe both groups by the basis of their common feature (e.g. group 1: round shape, group 2: square shape). Participants were asked to find as many different sorting rules as possible. The maximum of correct sorting rules was 18. On the second condition, SRP, 8 stimuli cards displaying a different card set were presented for 30sec. The stimuli cards were already divided into two groups, 4 cards each. After the timeout of 30sec, the examinee was asked to identify if there was a sorting rule or not, and if yes, describing both groups by the basis of their common feature. 15 slides showing the stimuli cards were provided during the sort recognition phase, with 9 correct sorting rules and 6 slides with no possible sorting rule. Visual examples of both conditions are shown in Figure 9 and Figure 10.

Two card sets were designed with 35 combination possibilities and 18 conceptual rules. Sorting rules varied in their difficulty, ranging from obvious common concepts (e.g. color of a form, shape of the card) to more subtle uncommon concepts (e.g. position differences in objects, starting letter of displayed word or object). These different difficulties were implemented to limit possible floor or ceiling effects. On the first card set, 7 sorting methods were based on verbal-semantic information from stimulus words, 10 sorting methods were based on visual-spatial features or patterns on the card and 1 sorting method was a mix of both. On the second card set within the SRP only 15 of 35 possible combinations were used. 5 sorting methods were based on verbal-semantic information from stimulus words and 4 sorting methods were based on visual-spatial features or patterns on the card. Number of correct sorting rules on the FSP, and number of correct sorting rules detected during the SRP, were used for further analysis. The mean reaction time during the FSP was also measured but not considered, because of no effects discovered during preliminary analysis.

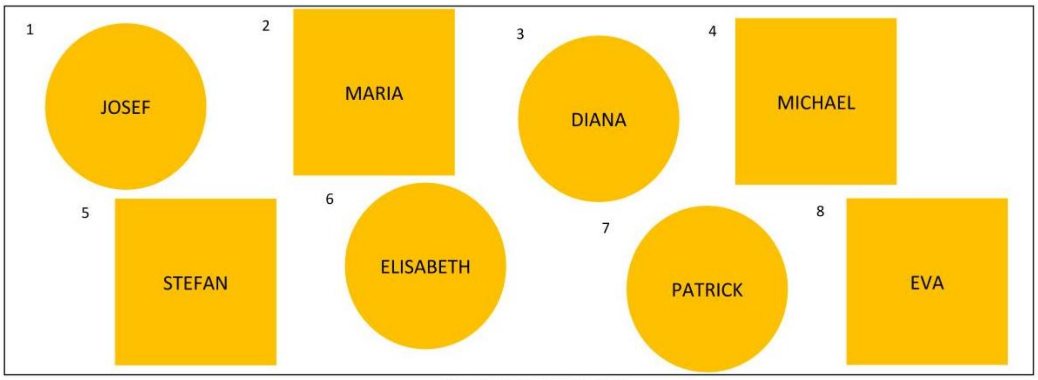

Figure 9: Example of the Computerized explorative sorting test Free Sorting Phase. With this card set, one rule would be to sort card number 1,3,6,7 by their common feature round shape, and 2,4,5,8 by their common feature square shape. Dividing the card set into men and women names would be the second rule.

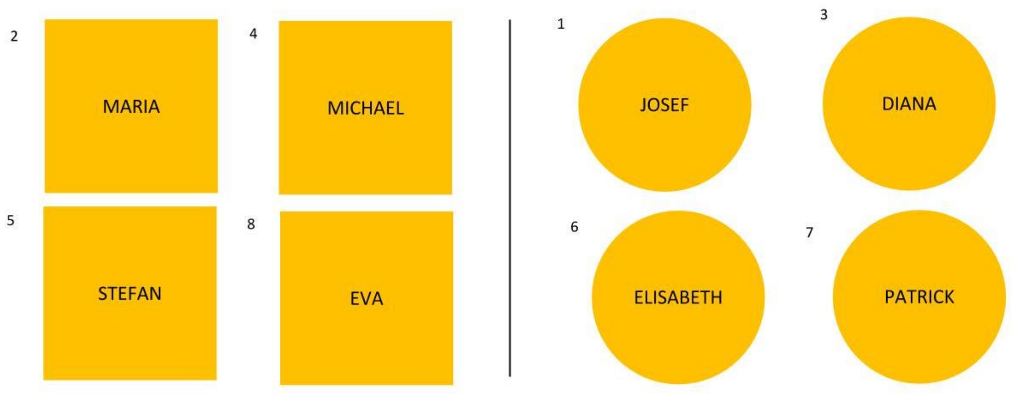

Figure 10: Example of the Computerized explorative sorting test Sort Recognition Phase. In this case there is a sorting rule possible. We would describe the group on the left by their common feature round shape, and the right group by their common feature square shape.

2.3.6. Athletic development questionnaire (ADQ):

Adapted and simplified from Côté et al. (2005) to fit the purpose of the study, the athletic development questionnaire (ADQ) was designed to identify the development background of athletes from their early ages on. While most questions about early activities and main sport involvement were included from the original questionnaire of Côté et al. (2005), questions about maturation individual and team milestones, height changes, age of their peers during different age episodes, intensity / effort / fun and injuries during training, and performance during every stage were excluded. The recent version of the ADQ that was used during this study is attached in the supplemental materials.

The retrospective interview was proposed by Côté et al. (2005) to collect valid information about sport specific achievements or events, involvement in sport activities, and other factors influencing their athletic path. Recalling activities and events that occurred years or decades ago could provide a serious challenge for athletes and the accuracy of the information provided cannot be guaranteed (Côté et al., 2005). Despite this limitations Côté et al. (2005) provided evidence that athletes are able to reliable report the number of hours they spent in sporting and training activities at different periods in their development. Reliable correlations were found during independent interviews between training estimates of parents and training estimates of their children within a small sample size of 13 parents of 15 athletes (Côté et al., 2005). Although detailed objective training logs would be superior to interviews, the agreement between parents' and athlete's estimation provide us with robust evidence for reliable and valid information. Especially concerning early childhood sport activities, that are often hard to recall for athletes and may be vague. The questionnaire was filled out with the athletes by trained interviewers in a qualitative one on one setting, to ensure valid and complete information. Information regarding education, experience in their main sport, and number of international tournaments in their main sport was assessed. To measure involvement in various sport activities in hours per year, the athletes provided information of all sports they performed on a regular basis for every year since age four until present. This age cutoff was used because most athletes in this sample size were unconfident in giving accurate information regarding athletic activities before the age of four. Regular basis was defined by three to six months of continued engagement or regular yearly involvement, like ski trips for one week every year. The choice of including sports in the questionnaire was solely left to the athletes. To better recall episodic memory, athletes were asked for training hours per week and training months per year for every age. Questions like "When was the first time you engaged in this sport?" and "How did your involvement in this sport change the next year?" aided the athlete to provide more accurate information. An example of a those involvement episodes as filled out with the athletes is shown in Figure 11.

Sport	Age 8		Age 9		Age 10	
	Hours per week	Months per year	Hours per week	Months per year	Hours per week	Months per year
Swimming	3	9	3	9	6	10
Tennis			8	2	8	3

Figure 11: Example of ADQ

In the final analysis, sports were then grouped for each athlete following the taxonomy for sport type mentioned earlier (Singer, 2000; Voss et al., 2010). Guided by Piaget's theory of cognitive development (Piaget, 1970) and the developmental model of sport participation (Côté & Vierimaa, 2014) several age episodes for involvement were defined, in order to reflect different stages and phases in an athlete's life. The age episodes were defined as: 4-7; 8-12; 4-12; 13-17; 18-present. Age episode 4-7 was selected to fit the phase of the entry into sports (Côté, 1999; Côté et al., 2007; Côté & Vierimaa, 2014) and the preoperational stage (Piaget, 1970) that lasts from age 2 until age 6 or 7. Episode 8-12 represents the sampling years that could end at about age 13 (Côté & Vierimaa, 2014) and the concrete operational stage (Piaget, 1970) that also lasts until age 12 or 13. Episode 4-12 is a combined measure for all involvement during early childhood. Age episode 13-17 reflects Piaget's (1970) formal operational stage that lasts from 12 or 13 until adulthood and specializing and investment years of the developmental model of sport participation (Côté, 1999; Côté et al., 2007; Côté & Vierimaa, 2014). The last episode, 18-present is a measure for all sportive involvement during adulthood and in most sports' eligibility for the highest competitive level. Although these stages are not perfectly accurate for every individual it enables comparability within the sample size. For every age episode we used the total involvement for all sports in hours and total involvement in hours for static, interceptive, and strategic sports each. Number of years competing at the highest level of their main sport, number of different sports and first entry into regular sports were also used as metrics in the analysis.

Additionally, music and creative involvement was assessed, since findings indicate that those activities have the potential to highly improve EF (Diamond & Ling, 2016; Moreno et al., 2011). Music involvement was defined when participants learned or played an instrument. Creative involvement was defined with activities that incorporated drawing, dancing, acting or film making. Furthermore, media and video gaming involvement was assessed for a better understanding of broad activities that might contribute to EF (Colzato, Van Leeuwen, Van Den Wildenberg, & Hommel, 2010; Glass, Maddox, & Love, 2013).

2.4. EF Construct measures

The metrics measured and further reported are summed up in table 2 below. Giving the explorative nature of the CEST we analyzed all variables from this test as a separate construct.

Table 2: Summary of all assessed executive function variables and their abbreviations used and reported in this study.

Construct	*Variable*	*Test*	*Abbreviation*
Working memory	Number of correct responses during 2-back test	2-back test	2B-CORR
	Number of false responses during 2-back test	2-back test	2B-FALSE
Inhibition	Mean reaction time on congruent stimuli during the flanker test	Flanker test	FT RT con
	Mean reaction time on incongruent stimuli during the flanker test	Flanker test	FT RT incon
	Difference between mean RT of correct decisions on congruent and mean RT of correct decisions on incongruent stimuli in percent during the flanker test	Flanker test	FT RT diff incon-con
Cognitive flexibility / shifting	Errors on stimuli showing red arrows during the complex flanker test	Flanker test	FTS errors red
	Mean reaction times for stimuli showing red arrows during the complex flanker test	Flanker test	FTS RT red
	Reaction time difference of red arrows and congruent stimuli during the complex flanker test	Flanker test	FTS diff red-con
	Time of completion for D-KEFS Trail making test Condition 4	Trail making test	TMT Cond4
	Total number of correct designs drawn over all 3 conditions from the D-KEFS Design Fluency test	Design Fluency test	DFTC
Perceptual / processing speed	Time of completion for D-KEFS Trail making test Condition 2	Trail making test	TMT Cond2
	Time of completion for D-KEFS Trail making test Condition 3	Trail making test	TMT Cond3
Problem solving / rule detection	number of correct sorting rules on the free sorting phase of the computerized explorative sorting test	computerized explorative sorting test	FSP corr
	number of correct sorting rules detected during the sort recognition phase of the computerized explorative sorting test	computerized explorative sorting test	SRP corr rules

2.4.1. ADQ variables

The vast amount of metrics used in the initial analysis was further broken down to the following most important ones. Static, interceptive, strategic and total sport involvement lifetime. Age episodes from 4 to 12yrs, 13 to 17yrs, 18yrs to present and lifetime for static, interceptive, strategic sports each. Years at highest competition level, number of different sports performed during an athlete's career, age with first entered into regular sports, and total hours of music involvement (TM Inv).

2.5. Procedure

The interviews and assessments were conducted between April and October of 2018 at training facilities of the respective teams and athletes or in the laboratory of the University of Vienna. Assessment procedure was standardized and kept chronological constant. After receiving information regarding the study and giving informed consent the athletes conducted the D-KEFS DF test, then the FT, followed by the FTS, the 2-back test and the CEST. The D-KEFS TMT was then administered in a one on one setting before the ADQ was conducted. Practice tasks with immediate feedback on the correctness of their responses were performed before all tests in order to assure familiarization with the tasks. Pen and paper was used for the DF test and the TMT. All other tests were conducted via notebook on a 17in screen, using the software QDesigner (© amescon). To ensure privacy of data, all tests and the questionnaire were coded with assigned numbers that are listed in a separate file only accessible by the author.

2.6. Statistical analysis

All statistical analyses were carried out using SPSS 21.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive data were calculated and reported as means and standard deviations (SD). Assumptions of normal distribution was assessed using the Kolmogorov-Smirnov test. Since the preliminary focus was getting insights about the differences between main sport types of athletes, MANCOVAS were performed with age as the covariate to account for developmental age-related effects (Huizinga, Dolan, & van der Molen, 2006; Krenn et al., 2018; Vestberg et al., 2017). For each EF construct MANCOVA, the respective EF construct variables mentioned earlier were used as the dependent variable. A significant effect of education was detected during the MANOVA, but only for the WM construct ($F(6,104) = 2.31$, $p = .039$, $\eta 2 = 0.118$) and thus was not further incorporated as a covariate. Regarding the homogeneity of the sample, the non-significant impact of education is reasonable, since 84% of the participants did have a high school diploma and 57% of all participants did attend college or university at the time of the assessments. Media and video game involvement was not included for further analysis due to non-significant effects on EF construct measures during preliminary analysis.

Pearson product-moment correlation coefficient was used to review intra-construct correlations. To gain insights into probable relations between EF construct variables and metrics of sport development from the ADQ, two tailed Spearman's rank correlation coefficient was calculated, due to the non-normal distribution of the ADQ metrics.

Multiple Regressions with forced entry were performed to find linear correlations between sport type involvement and EF. For every age episode which was defined in the ADQ (4-12yrs., 13-17yrs, 18yrs.-present, lifetime involvement), the assessed EF variables were used as dependent variable. Total involvement of static sports (TI-stat), total involvement of interceptive sports (TI-inter), and total involvement of strategic sports (TI-strat) were used as independent variables. As an additional step, a second multiple regression model was tested, incorporating total music involvement (TI-music) as a fourth independent variable. Multicollinearity was examined using Pearson product-moment correlation coefficient. As a follow-up, bivariate correlations of all sport type episodes and EF construct variables were performed to further understand interactions. Durbin-Watson statistic was used to detect assumptions of errors in regressions. B values, standard error of B and β values were then reported respectively.

Statistical significance was generally accepted at $p < .05$. Effect sizes were interpreted using the reference values of Small ($r=0.2$), Medium ($r=0.5$) and Large ($r=0.8$) from Cohen (1988). One athlete did not perform the TMT and the CEST appropriately and therefore both of his test results were excluded for further analysis. Two athletes did not finish the TMT Cond4 correctly, thus their results on TMT Cond4 were also excluded. Due to a technical malfunction the results of the 2-back test of one athlete were also corrupt and therefore excluded for further analysis.

For the WM construct, significant correlations were found between 2B-CORR and 2B-FALSE ($r(56) = 0,30$, p 0,02). For the INH construct, significant correlations were found between FT RT con and FT RT diff incon-con ($r(57) = 0,418$, p 0,02), and between FT RT con and FT RT incon ($r(57) = 0,921$, $p < 0,001$). Although the high correlations make sense when considering the task of the test, we only used FT RT diff incon-con as main metric for inhibition in further analysis. For the CF construct, bivariate correlations were significant between DFTC and FTS errors red ($r(56) = 0,28$, p 0,03), and between FTS errors red and FTS RT red ($r(56) = 0,28$, p 0,03). The intra-construct correlation for the CEST revealed significant effects between FSP corr and SRP corr answers ($r(56) = 0,30$, p 0,025), between FSP corr and SRP corr rules ($r(56) = 0,36$, p 0,007) as well as SRP corr answers and SRP corr rules ($r(56) = 0,83$, $p < 0,001$) Furthermore we conducted bivariate correlation for the CEST with all other EF construct variables and discovered significant correlations with 2B-CORR (r(55) = 0,44, p 0,001), 2B-FALSE (r(55) = 0,28, p 0,038), TMT Cond2 (r(56) = 0,29, p 0,033) and the DF Condition 3 Switching Subtest (r(55) = 0,32, p 0,017). This led to the assumption that working memory, processing speed and switching components contribute to performance at the CEST. The small to moderate correlation coefficients with all other tests provided confidence for the independency of the CEST. For the PS construct, TMT Cond2 and TMT Cond3 were correlated (r(56) = 0,54, p >0,001). TMT Cond 4 was also significantly correlated with TMT Cond 2 (r(54) = 0,46, p >0,001) and TMT Cond 3 (r(54) = 0,41, p 0,002). Despite this results, all variables, except those for the inhibition construct, met the r = < 0.90 requirement for conducting MANCOVAS (Tabachnick & Fidell, 2007).

3. Results

3.1. Main sport type

The MANCOVA revealed a significant multivariate effect of main sport type (F(6,102) = 2.404, p = .033, η^2 = 0.124) for the CEST construct, the covariate age did not contribute significantly (F(3,50) = 1,253, p = .3, η^2 = 0.07). In the univariate analysis the main sport type effect was then significant for the variables FSP corr (F(2,52) = 3.701, p = .031, η^2 = 0.125) and SRP corr rules (F(2,52) = 4.348, p = .018, η2 = 0.143) with the interceptive group recognizing significantly more sorts than the static group for FSP corr (p = .039, interceptive (M = 11.25 SD = 2.375) static (M = 8.41 SD = 3.043)) and SRP corr rules (p = .017, interceptive (M = 3.00 SD = 1.604) static (M= 1.35 SD = 1.115)).

For all other EF constructs the impact of main sport type was non-significant during multivariate analysis. However, there was a significant univariate effect of main sport type for the variables FT RT diff incon-con (F(2,53) = 3.738, p = .03, η^2 = 0.124) and the TMT Cond4 (F(2,49) = 4.063, p = .023, η^2 = 0.142). Significant difference between the interceptive and the strategic group was found during pairwise comparison for the main metric of inhibition, FT RT diff incon-con, (p = .044, interceptive (M = 8.25 SD = 3.62) strategic (M= 12.66 SD = 4.55)), and for TMT Cond4 (p = .036, interceptive (M = 39.25 SD = 8.430) strategic (M= 53.66 SD = 11.965)). Hence, the interceptive group had a lower difference between reaction times of congruent and incongruent stimuli during the Flanker test and finished the switching condition of the TMT faster than the strategic group. The means and standard deviations for all EF constructs and variables shown in Table 3 reveal no clear trend in favor of interceptive over strategic sports or vice versa but do indicate inferior performance of static sports throughout most variables.

Table 3 – Means and standard deviations for all EF constructs and variables

		Static (1) (n=17)		Interceptive (2) (n=8)		Strategic (3) (n=32)	
Constructs	*Variables*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Cognitive Flexibility	FTS RT red (msec)	680.18	68.08	679.25	31.26	648.65	55.35
	FTS diff red-con (msec)	94.12	37.18	90.63	27.70	94.29	40.91
	FTS errors red	2.12	2.09	1.50	1.60	1.77	1.38
	TMT Condition4 (sec)	46.56	12.80	39.25	8.43	53.03	12.24
	DF total correct	39.88	7.32	41.00	13.79	39.84	10.55
Working Memory	2Back correct	17.35	3.37	17.38	2.33	18.32	2.99
	2Back false	6.18	4.65	5.25	2.82	4.81	3.70
CEST	FSP correct	8.41	3.04	11.25	2.38	10.03	2.48
	SRP correct answers	6.59	1.94	8.38	2.67	6.81	2.17
	SRP correct rules	1.35	1.12	3.00	1.60	2.00	1.24
Inhibition	FT RT diff incon-con (%)	10.35	5.22	8.25	3.62	12.66	4.55
	FT RT con (msec)	461.82	48.13	448.88	35.62	442.34	53.98
	FT RT incon (msec)	508.24	43.54	486.38	43.60	497.47	55.55
	FT errors incon	4.35	2.80	3.25	2.05	4.22	3.10
Perceptual speed	TMT Condition2 (sec)	24.59	7.92	17.63	2.93	22.16	6.65
	TMT Condition3 (sec)	22.00	6.72	16.50	5.50	23.35	10.29
	TMT Scaled Score of Condition 2 & 3	12.88	2.23	14.50	1.31	12.68	2.61

Note: FTS = flanker task switching; RT = reaction time; con = congruent; incon = incongruent; diff = difference; TMT = Trail making test; DF = Design Fluency test; CEST = computerized explorative sorting task; FSP = free sorting phase; SRP = sort recognition phase; FT = flanker test;

3.2. Sport development and sport type involvement

Descriptive values of sport type and music involvement are displayed in Table 4. the Spearman's rank correlations of sport type involvement and EF construct variables are displayed in the form of a correlation matrix in Table 5. Descriptive values of competition level and other metrics from the ADQ are shown in Table 6 with the Spearman's rank correlation of those ADQ variables with the EF construct variables displayed in Table 7. Supplemental to that, two multiple linear regression models were performed to examine the influence of certain sport type involvement on EF construct variables. The model contained the sport type involvement during the age episode, while additionally incorporating their total life involvement of music, representing the potential influence of music on EF as stated earlier. Due to the novelty of the study design, various results were reported to provide insights.

Table 4 – Descriptive values of sport type and music involvement grouped by the main sport type of athletes

		MSP Static (n = 17)		MSP Interceptive (n = 8)		MSP Strategic (n = 32)	
	Age episode	*M*	*SD*	*M*	*SD*	*M*	*SD*
Static Involvement (hours)	4-12yrs	1,369	1,107	1,094	649	338	538
	13-17yrs	2,753	1,807	519	712	268	535
	18yrs-present	8,086	7,992	9	25	605	1,571
	Lifetime	12,209	6,597	1,621	825	1,211	2,131
Interceptive Involvement (hours)	4-12yrs	549	872	1,515	767	776	754
	13-17yrs	216	382	2,970	588	652	1,058
	18yrs-present	280	565	2,965	2,127	794	2,515
	Lifetime	1,045	1,549	7,450	3,023	2,222	3,718
Strategic Involvement (hours)	4-12yrs	121	243	830	814	1,187	959
	13-17yrs	158	282	425	632	2,137	1,399
	18yrs-present	124	287	73	118	5,544	5,206
	Lifetime	404	590	1,328	1,543	8,868	6,408
Total Sport Involvement (hours)	4-12yrs	2,039	1,553	3,438	1,223	2,301	1,240
	13-17yrs	3,127	1,822	3,914	1,715	3,057	1,560
	18yrs-present	8,491	8,351	3,047	2,094	6,943	6,724
	Lifetime	13,657	7,028	10,399	3,626	12,301	8,459

Music involvement

		MSP Static		MSP Interceptive		MSP Strategic	
Total Music Involvement (hours)	Lifetime	873	1148	886	1223	547	859

Note: MSP = main sport;

Table 5 – Spearman's rank correlation of sport type involvement and EF construct variables

	Static Involvement				Interceptive Involvement				Strategic Involvement				Total Sport Involvement			
	Age episode				*Age episode*				*Age episode*				*Age episode*			
	4-12yrs	13-17yrs	18yrs-present	Life time	4-12yrs	13-17yrs	18yrs-present	Life time	4-12yrs	13-17yrs	18yrs-present	Life time	4-12yrs	13-17yrs	18yrs-present	Life time
FTS RT red[a]	0.132	0.066	0.037	0.177	-0.245	-0.162	-0.203	-0.198	-0.115	-0.212	**-0.365***	**-0.368***	-0.170	-0.191	**-0.281***	-0.243
TMT Condition4[a]	-0.254	-0.150	-0.031	-0.152	-0.215	-0.141	-0.022	-0.189	0.220	**0.433***	**0.399***	**0.405***	-0.153	-0.070	0.195	0.116
DFTC[a]	0.143	0.110	0.238	0.198	**0.433***	**0.317***	**0.308***	**0.411***	-0.051	-0.101	0.071	0.003	**0.265***	0.059	0.238	**0.285***
2BACK-corr[b]	-0.018	-0.018	0.053	-0.054	0.120	0.096	0.100	0.048	0.113	0.147	0.182	0.159	0.106	0.056	0.138	0.092
2BACK-false[b]	0.062	0.043	-0.150	0.029	-0.185	-0.091	-0.162	-0.109	-0.078	-0.104	-0.167	-0.115	-0.010	0.243	-0.168	-0.004
FSP corr[c]	-0.097	-0.173	-0.077	-0.116	**0.380***	**0.325***	0.255	**0.328***	0.050	-0.005	0.128	0.082	0.130	-0.088	0.055	-0.060
SRP corr rules[c]	-0.089	**-0.275***	**-0.278***	-0.241	0.111	0.201	0.119	0.113	0.183	0.112	-0.027	0.021	0.167	-0.028	-0.228	**-0.298***
FT RT diff incon-con[d]	-0.133	0.054	0.027	-0.207	0.215	-0.018	0.016	0.074	-0.057	0.055	**0.298***	0.179	-0.030	0.031	0.101	-0.014
FT RT con[d]	-0.108	-0.135	-0.029	0.017	**-0.422***	**-0.262***	**-0.276***	**-0.388***	-0.021	-0.096	**-0.289***	-0.234	**-0.287***	**-0.303***	-0.223	**-0.287***
FT RT incon[d]	-0.146	-0.124	-0.042	-0.077	**-0.378***	**-0.314***	**-0.320***	**-0.415***	-0.032	-0.096	-0.229	-0.209	**-0.310***	**-0.312***	-0.221	**-0.329***
TMT Condition2[e]	-0.101	-0.100	0.026	-0.016	**-0.552***	**-0.477***	**-0.381***	**-0.548***	-0.018	0.114	-0.095	-0.054	**-0.338***	-0.156	-0.019	-0.122
TMT Condition3[e]	0.049	0.038	0.048	0.046	**-0.335***	**-0.402***	**-0.343***	**-0.412***	0.069	0.240	0.069	0.110	-0.054	0.072	-0.073	-0.031
TMT Scaled Score of Condition 2&3[e]	0.041	0.068	-0.003	0.047	**0.413***	**0.434***	**0.327***	**0.479***	-0.118	**-0.280***	-0.011	-0.092	0.143	0.007	0.074	0.080

Note: *. Correlation is significant p < .05 (two tailed), green cells mark an impact that produces sig. better EF test results, red cells mark an impact that produces sig. worse EF test results.
EF Constructs: a) cognitive flexibility b) working memory c) CEST d) inhibition e) perceptual speed
FTS = flanker task switching; RT = reaction time; con = congruent; incon = incongruent; diff = difference; TMT = Trail making test; DFTC = Design Fluency total correct; corr = correct; FSP = free sorting phase; SRP = sort recognition phase; FT = flanker test;

Table 6 - Descriptive values of competition level and other ADQ variables grouped by the main sport type of athletes

	MSP static (n=17)		MSP interceptive (n=8)		MSP strategic (n=32)	
	M	SD	M	SD	M	SD
Number of European Championships	3.71	3.20	1.63	3.16	1.84	3.16
Number of World Championships	1.06	1.35	1.38	2.67	1.78	3.18
Number of Olympic Games	0.24	0.44	0.00	0.00	0.06	0.25
Years competing at the highest level in their MSP	1.59	1.12	2.25	0.89	2.81	1.89
Number of different sports participated	4.00	2.65	5.75	1.39	6.22	2.43
First entry into regular sports	6.12	2.78	4.63	1.06	5.31	1.42
First entry into highest level in their MSP	20.06	7.29	18.50	1.77	19.69	4.78
MSP AE 4-7yrs (hours)	185	219	13	37	55	118
MSP AE 8-12yrs (hours)	957	797	959	638	568	549
MSP AE 4-12yrs (hours)	1,141	950	972	631	623	601
MSP AE 13-17yrs (hours)	2,619	1,825	2,714	488	1,835	1,206
MSP AE 18-present (hours)	7,866	7,811	2,791	1,949	5,422	5,214
MSP Total Lifetime (hours)	11,626	6,395	6,477	2,525	7,880	5,951

Note: MSP = main sport; AE = age episode;

Table 7 – Spearman's rank correlation of ADQ variables and EF construct variables

	Years at highest competition level	Number of different sports	First entry into regular sports (years)	Total Music Involvement (hours)
FTS RT red[a]	**-0.313***	-0.178	**0.280***	**-0.287***
TMT Condition4[a]	0.247	-0.008	**0.290***	**-0.368***
DFTC[a]	0.171	**0.371***	**-0.402***	**0.360***
2BACK-corr[b]	0.177	0.18	-0.177	**0.304***
2BACK-false[b]	-0.171	**-0.273***	0.195	-0.223
FSP corr[c]	0.212	0.163	**-0.278***	0.261
SRP corr rules[c]	0.07	0.034	-0.044	-0.016
FT RT diff incon-con[d]	0.242	0.023	0.07	0.096
FT RT con[d]	-0.207	**-0.301***	**0.284***	**-0.322***
FT RT incon[d]	-0.085	**-0.349***	**0.374***	**-0.275***
TMT Condition2[e]	-0.062	**-0.457***	**0.480***	-0.246
TMT Condition3 [e]	0.043	-0.187	**0.541***	**-0.294***
TMT Scaled Score of Condition 2&3 [e]	-0.018	0.244	**-0.496***	**0.268***

*. Correlation is significant p < .05 (two tailed), green cells mark an impact that produces sig. better EF test results
EF Constructs: a) cognitive flexibility b) working memory c) CEST d) inhibition e) perceptual speed
FTS = flanker task switching; RT = reaction time; con = congruent; incon = incongruent; diff = difference; TMT = Trail making test; DFTC = Design Fluency total correct; corr = correct; FSP = free sorting phase; SRP = sort recognition phase; FT = flanker test;

3.2.1. Cognitive Flexibility

The conducted correlation analysis revealed significant correlations between cognitive flexibility construct variables and metrics from the athletic development questionnaire, more precisely displayed in Table 5. Most notably the FTS RT red was correlated with strategic involvement during AE 18yrs-present $r_S = -.37$ $p = .006$ and also with total sport involvement during AE 18yrs-present $r_S = -.28$ $p = .036$ among other metrics. DFTC and Interceptive sport involvement displayed significant correlations through all AE and for TI-inter life $r_S = .41$ $p = .002$. Furthermore, DFTC correlated with First reg sport $r_S = .40$ $p = .002$ and TM Inv $r_S = .36$ $p = .006$. TM inv also had a positive impact on all other CF construct variables, significantly correlating with FTS RT red and TMT Cond4 as shown in Table 7.

Multiple linear regression was calculated to predict CF based on TI-static for every age episode, TI-interceptive for every age episode, TI-strategic for every age episode, and TI-music. A significant regression equation was found for TMT Cond 4 during all age episodes (AE). AE 4-12 ($F(4,48) = 3.109$, $p = .024$) with an R^2 of .206, AE 13-17 ($F(4,48) = 4.600$, $p = .003$) with an R^2 of .277, AE 18-present ($F(4,48) = 5.535$, $p = .001$) with an R^2 of .316, TI-life ($F(4,48) = 5.555$, $p = .001$) with an R^2 of .316. As shown in Table 8 total music involvement, static life involvement and strategic life involvement predicted TMT Cond4 scores. For DFTC a significant regression equation was found for the AE 4-12 ($F(4,51) = 3.381$, $p = .016$) with an R^2 of .210. Interceptive involvement during AE 4-12 was the sole significant predictor. These results indicate that involvement in interceptive sports, involvement in strategic sports after the age of 18, first entry into regular sports, and time spent with music are beneficial for cognitive flexibility construct measures. High amounts of lifetime static and lifetime strategic involvement do seem to have a negative impact on TMT Cond4 performance as shown in Table 8.

Table 8 - Multiple regression model for CF constructs with sport type involvement and TM Inv

	DFTC			TMT Condition4		
	B	B SD	β	B	B SD	β
Constant	35.8	2.551		54.249	3.287	
Inter AE 4-12yrs	0.005	0.002	**0.393***	-0.002	0.002	-0.163
Stat AE 4-12yrs	-0.001	0.002	-0.047	-0.002	0.002	-0.134
Strat AE 4-12yrs	0	0.001	-0.039	0.002	0.002	0.11
TM Inv	0.001	0.001	0.139	-0.004	0.002	**-0.297***
Note: R^2= .21, *p < .05				Note: R^2= .206, *p < .05		

	TMT Condition4		
	B	B SD	β
Constant	47.323	2.958	
Inter Life	0	0	-0.125
Stat Life	0.001	0	**0.305***
Strat Life	0.001	0	**0.35***
TM Inv	-0.004	0.002	**-0.356***
Note: R^2= .316, *p < .05			

Note: DFTC = Design fluency total correct, TMT = Trail making test; Inter = Interceptive; Stat = static; Strat = strategic; TM Inv = Total music involvement;

3.2.2. Working memory

No representative correlations with sport involvement were discovered regarding the 2-back task. Multiple regression also did not yield any significant results.

3.2.3. Problem solving / Rule detection

Interceptive sport involvement during early years did correlate with FSP corr as shown in Table 5 and also with interceptive life involvement $r_S = .328$ $p = .014$. Static sports negatively correlated with SRP corr rules during AE 13-17 $r_S = -.275$ $p = .04$ and AE 18-present $r_S = -.278$ $p = .038$ as shown in Table 5, indicating a negative impact on CEST performance. First entry into regular sports also did correlate with FSP corr $r_S = -.278$ $p = .038$ but did have a negative impact on the CEST score. Surprisingly total sport involvement during an athletes' career (TSI life) also had a negative impact on SRP corr rules $r_S = -.298$ $p = .026$. Multiple linear regression was calculated to predict CEST based on TI-static for all age episodes, TI-interceptive for all age episodes, TI-strategic for all age episodes, and TI-music, but did not produce significant results. Performance on the CEST was therefore positively influenced by interceptive sport involvement and impaired by static sport involvement.

3.2.4. Inhibition

Most notably interceptive involvement correlated with reaction times during the FS during all AE. FT RT con $r_S = -.388$ $p = .003$ and FT RT incon $r_S = -.415$ $p = .001$ both significantly correlated with lifetime interceptive involvement. Strategic involvement during age episodes 18yrs-present had positive impact on FT RT con $r_S = -.289$ $p = .029$ but did lead to inferior performance of FT RT diff incon-con $r_S = .298$ $p = .024$, leading to the interpretation that strategic involvement did benefit congruent reaction times, while incongruent reaction times still remained similar to all other sport involvements and therefore yielding greater differences between those tasks. Total sport involvement lifetime was additionally correlated with FT RT con $r_S = -.287$ $p = .03$ and FT RT incon $r_S = -.329$ $p = .013$, but not with FT RT diff incon-con. The multiple regression did not yield any significant results. Interceptive involvement, total sport involvement, number of different sports, first entry into regular sports, and music involvement all positively impacted reaction times of the FT as shown in Table 3 and Table 4 but the main metric measuring inhibition, FT RT diff incon-con, did not show considerable effects.

3.2.5. Perceptual speed

As displayed by the correlation matrix in Table 5 and Table 7, a significant impact of interceptive involvement through all age episodes and for lifetime involvement was discovered. Lifetime interceptive involvement had a moderate effect on TMT Cond2 r_S = -.548 p = <.001, TMT Cond3 r_S = -.412 p = .002 and also on the TMT SSofCond2&3 r_S = -.479 p = <.001. Supporting these results reaction times during the Flanker task showed significant correlations with interceptive involvement lifetime involvement (FT RT con: r_S = -.388 p = .003, FT RT incon: r_S = -.415 p = .001) and all other AE. Furthermore, first entry into regular sport correlated with TMT Scaled Score ofCondition 2&3 r_S = -.496 p = <.001, as did TM inv r_S = .268 p = <.048. Number of different sports had moderate impact on TMT Cond2 r_S = -.457 p = <.001. Additionally, first entry into regular sports and number of different sports both correlated with reaction times during the Flanker task as shown in Table 7.

Multiple linear regression was calculated to predict perceptual speed based on TI-static for all age episodes, TI-interceptive for all age episodes, TI-strategic for all age episodes, and TI-music. A significant regression equation was found for TMT Cond2 during all age episodes as shown in Table 9 and for TMT Cond3 during age episode 13-17 (F(4,50) = 3.603, p = .012) with an R^2 of .224. For TMT Cond 2, interceptive involvement was a significant predictor during age episode 4-12yrs and age episode 13-17yrs, static involvement during age episode 18-present and Lifetime, and music involvement during all age episodes were as well significant predictors. For TMT Cond3 only strategic involvement during age episode 13-17yrs was a significant predictor. Results indicate that interceptive sport involvement, first entry into regular sport, music involvement, and number of different sports all contribute to TMT Cond2 and 3 performance and also to mean reaction times during the Flanker task. Static sports involvement seemed to hinder performance of perceptual speed measures.

Table 9 - Multiple regression model for PS constructs with sport type involvement and TM Inv

	TMT Condition2		
	B	B SD	β
Constant	26.720	1.728	
Inter AE 4-12yrs	-0.003	0.001	**-0.381***
Stat AE 4-12yrs	0.000	0.001	-0.014
Strat AE 4-12yrs	-0.001	0.001	-0.085
TM Inv	-0.002	0.001	**-0.249***

Note: R^2= .270, *p < .05

	TMT Condition2			TMT Condition3		
	B	B SD	β	B	B SD	β
Constant	26.698	2.040		19.474	2.692	
Inter AE 13-17yrs	-0.002	0.001	**-0.380***	-0.001	0.001	-0.124
Stat AE 13-17yrs	0.000	0.001	-0.099	0.001	0.001	0.190
Strat AE 13-17yrs	0.000	0.001	-0.100	0.002	0.001	**0.380***
TM Inv	-0.002	0.001	**-0.275***	-0.001	0.001	-0.156

Note: R^2= .250, *p < .05 | Note: R^2= .224, *p < .05

	TMT Condition2		
	B	B SD	β
Constant	23.587	1.163	
Inter AE 18yrs-present	0.000	0.000	-0.145
Stat AE 18yrs-present	0.001	0.000	**0.472***
Strat AE 18yrs-present	0.000	0.000	-0.069
TM Inv	-0.003	0.001	**-0.416***

Note: R^2= .388, *p < .05

	TMT Condition2		
	B	B SD	β
Constant	23.275	1.546	
Inter Life	0.000	0.000	-0.23
Stat Life	0.000	0.000	**0.397***
Strat Life	0.000	0.000	0.007
TM Inv	-0.003	0.001	**-0.364***

Note: R^2= .362, *p < .05

Note: TMT = Trail making test; Inter = Interceptive; Stat = static; Strat = strategic; TM Inv = Total music involvement;

4. Discussion

The aim of this study was to reveal differences in EF by considering the development trajectories of elite and expert athletes. By combining the current research about differences in EF between expert and novice players, and differences in EF when comparing sport types it was expected to distinguish between static, interceptive and strategic sports (Jacobson & Matthaeus, 2014; Kida et al., 2005; Krenn et al., 2018; Voss et al., 2010). Consideration of past sport and creative involvement was also expected to detect differences in certain EF constructs by taking the broad cognitive skill transfer theory, deliberate practice and deliberate play involvement into account (Côté & Vierimaa, 2014; Furley & Memmert, 2011; Jacobson & Matthaeus, 2014; Taatgen, 2013).

Although sample sizes of static, interceptive, and strategic athletes were considerably unequal distributed, the detectable differences in main sport type favored interceptive athletes over all other athletes on certain measures of inhibition and cognitive flexibility. Interceptive athletes had lower differences between congruent and incongruent reaction times during the Flanker task than static athletes, and also performed better on the sorting task. They finished the TMT Cond4 task faster than strategic athletes. This reflects the findings of previous research which reported benefits of interceptive sports when compared to static and strategic sports for inhibition, task switching and problem solving (Jacobson & Matthaeus, 2014; Kida et al., 2005; Wang et al., 2013; Yu et al., 2017) whereas others only found differences in perceptual speed (Voss et al., 2010; Yongtawee & Woo, 2017).

The conducted correlation analysis and multiple regression however revealed a clearer picture in our sample of how involvement in certain sport types can explain changes in EF. Past interceptive involvement was associated with better processing speed and showed small to medium correlations with scores on the CEST and the Design fluency test, also indicating benefits of interceptive sports on cognitive flexibility. During the analysis it became visible that the CEST was distinguishing between certain sport types and could provide an additional tool for assessing further aspects of EF. With the influence, reported earlier, of working memory, processing speed and switching components on CEST performance, it is arguable that the sorting task may tap into more complex cognitive tasks and thus show differences between cognitive highly demanding and less demanding sports. This assumption was further supported by a significant negative impact of past static involvement from age 13 to present on correct sorts during the free sorting phase (FSP corr). Additionally, the descriptive analysis in Table 3 displayed that static athletes had the lowest score on both CEST variables, while interceptive athletes had the highest. The negative impact of first entry into regular sports and total sport involvement during an athlete’s career on the CEST could be biased by athletes that mainly competed in static sports in their life and should be interpreted with caution. In our sample size, athletes from static sports usually entered regular sport at a much younger age and also accumulate more training hours than athletes competing in strategic or interceptive sports, as displayed in Table 4 and Table 6. Interceptive involvement from 4 to 17 years showed to be a significant predictor for TMT Condition2, a measure for perceptual speed, during the multiple regression analysis. Early interceptive involvement during age 4 to 12 also predicted scores for DFTC. Past static involvement and especially static involvement in adulthood after the age of 18 was a significant predictor for TMT Condition2 by increasing completion times, thus having a negative impact on performance. These results are highly consistent with findings about superior perceptual speed in interceptive athletes over static athletes (Voss et al., 2010; Yongtawee & Woo, 2017) and athletes with extensive interceptive sport involvement (Ishihara et al., 2017; Supinski et al., 2014), further strengthening the assumption that extensive involvement in interceptive sports could enhance perceptual speed and therefore is detectable in elite interceptive athletes that accumulated considerable high amounts of interceptive involvement through their career. These effects could result from interceptive sport demanding rapid reactions to a stimulus, for example accurately returning a tennis serve at about 250km/h. In static sports on the other hand, reacting to an external stimulus is often not relevant giving the self-paced nature of those sports. Environmental changes during static sport competition oftentimes do not occur fast and unexpected, thus not placing high demands on the quick processing of information.

Past strategic involvement and particularly during adulthood, after the age of 18, did result in better cognitive shifting, significantly improving the mean reaction times on red stimuli during the Flanker task. This helps to further clarify the results from Krenn et al. (2018) who consequently also found faster reaction times for the FTS on red stimuli for strategic athletes when compared to static athletes. The negative impact of past strategic involvement on TMT Condition4 finishing time is somehow surprising, considering previous research (Jacobson & Matthaeus, 2014; Krenn et al., 2018; Voss et al., 2010) and the assumed high cognitive demands of strategic sports. Because errors during the TMT Condition4 can greatly impair the score, it can only be vaguely hypothesized that errors and mistakes are common for creating solutions in strategic sports. Regarding this particular sample size, a very small hint for the poor scores could be the negative impact of strategic involvement after the age of 18 on the main metric of inhibition, but these results need careful interpretation. Involvement in music was significantly improving scores for cognitive flexibility tasks, working memory and perceptual speed, correlating with reaction times of the FTS on red stimuli, all conditions of the TMT, DF total score, number of correct reactions during the 2-

back task and reaction times during the Flanker task. Past involvement in music was also a significant predictor for all conditions of the TMT during multiple regression analysis. These results go in line with findings that support beneficial effects of music training on EF (Bugos et al., 2007; Degé et al., 2011). The number of different sports performed during an athlete's career did benefit scores on perceptual speed and correlated with total correct during the Design fluency test. This further provides support for the proposed importance of diverse experiences related and unrelated to the main sport in order to obtain better insights into EF (Côté & Vierimaa, 2014; Diamond & Ling, 2016).

4.1. Limitations

Several limitations have to be considered regarding the generalizability of the presented results. Although the sample size (n=57) was high enough to detect significant results the distribution of static, interceptive and strategic athletes was highly unequal and would have benefited from more athletes that competed in static and interceptive sports. This could have further limited the possibility to detect influences of main sport type on EF. Although in the light of the main purpose, to detect developmental effects, it did not impair the evaluation of data. A male bias was also observed in the sample, particularly in strategic sports (25 male / 7 female) but gender differences for EF measures were not detectable since men and women were uneven distributed. Further studies would benefit from equal distribution between sport type clusters and from greater sample sizes. To gain more insights to the complex connections between sport type involvement and EF, future studies also could incorporate structural equation models and mediator/moderator analysis. In this study, the conduction of several multiple regression calculations could have led to an increase of the alpha error.

As mentioned earlier education levels were homogenous with only few athletes not possessing a high school diploma. Level of performance and sport expertise was furthermore hard to compare between athletes of one sport and between the recruited sports since the competition athletes face inside their sports can differ greatly. Even if competitions were conducted on an international level, it was impossible to objectively compare athletes' performance on a single variable. Still the total involvement in their main sports was congruent with studies assessing training hours of expert athletes (Baker et al., 2003; Hornig et al., 2016). Hornig et al. (2016) reported that top-level professional soccer players accumulated 4532 ± 1587 hours in their main sport before reaching the national team, and Baker et al. (2003) found that strategic athletes from basketball, netball and field hockey accumulated 3939 ± 1769 hours in their main sport before reaching their respective national team.

With most athletes in this sample size presumably entering the highest level of competition at around age 18 their respective accumulated mean hours in their main sports before age 18 were 4,902 ± 3,792 hours for static, 4,658 ± 1,794 hours for interceptive and 3,081 ± 2,474 for strategic sports. It has to be mentioned that athletes from the strategic sport cluster varied greatly regarding their respective competition level. American football players were exclusively dedicated amateur athletes. Although most of them were part of the national team that was European vice champion, very few states in Europe compete at a high level in this sport. Regarding the basketball players in our sample size it must be mentioned that the Austrian league is not regarded as one of the better ones in Europe and the Austrian national team did not qualify for a European championship in the last decades. Furthermore, import players from North America often occupy vital roles in basketball teams, mostly leaving only 3 starting spots open for Austrian Players. Hence, most of the players in our sample will fill a backup or situational role during the upcoming season. For future research, the assessment of performance variables to compare athletes within their respective main sport would clarify an athlete's elite status within his sport.

Although the focus during the recruiting process was on sports that were clearly assignable to static, interceptive or strategic sports, further research is needed to better distinguish sports by their cognitive demands, thus eliminating possible uncertainties. Especially the interceptive cluster covers a broad spectrum of sports, therefore increasing the risk that those sports do not share the same cognitive demands. Under the current taxonomy cross-country skiing which still requires coordination between an object and the environment but is an extensive rather monotone activity is clustered with badminton where fast reaction is essential since the sport object can fly at a speed of 400km/h. Another limitation still exists concerning the retrospective interviews. The validity of this assessment was discussed earlier but variances of the assessed variables could exist, since athletes might not remember early childhood activities accurately and reporting exact values and hours spent per week for certain activities dating back more than 10 years can prove indeed challenging. Uncertainty still persists about the quality of the individual involvement in certain sports, since the deliberate cognitive involvement can be highly variable to the context, but still would be labeled as the same type of sport in the data. Despite the concentrated effort by conducting the interview in a qualitative setting, motivational factors and socially desirable behavior could contribute to variability of the information the athletes provided. While several tests were conducted to cover a broad spectrum of EF measures the categorization of constructs was challenging especially for the cognitive flexibility construct which is still the topic of operationalization efforts (Barbey, Colom, & Grafman, 2013; Diamond, 2013; Ionescu, 2012). Although the DF test and TMT have shown low test-retest correlations and discriminant validity, it is a common problem when assessing executive functioning (Delis et al., 2001; Delis et al., 2004). The results are furthermore restricted to the measurements used and do not represent a holistic coverage of EF and EF constructs.

5. Conclusion

This thesis displayed that specific sport type involvement affects measures of executive functions by detecting differences between static, interceptive and strategic sport involvement throughout an athlete's career. Although studies about expertise level, associated with long-term sport involvement also detected differences in EF (Ishihara et al., 2017; Nakamoto & Mori, 2008; Supinski et al., 2014), up to my current knowledge no research revealed the multifaceted impact that certain sport types and activities during an athlete's career can have on executive functioning. The results indicate that extensive interceptive sport involvement can improve measures of cognitive flexibility and perceptual speed. Extensive strategic sport involvement can furthermore improve cognitive shifting, whereas extensive static sports involvement did not improve EF. Along with current research recommendations can be made that involvement in cognitive demanding sports and versatile activities like playing an instrument or participating in several sports can improve certain cognitive abilities, especially cognitive flexibility and processing speed (Baker et al., 2003; Côté & Vierimaa, 2014; Jacobson & Matthaeus, 2014; Krenn et al., 2018; Voss et al., 2010). It further contributed to the broad skill transfer concept by showing that extensive time spent on an unrelated yet cognitive demanding task improved basic cognitive abilities (Allen et al., 2011; Furley & Memmert, 2011). Although the study emphasized the demand for investigating the development history of athletes, the scope was limited to the small sample size and the measures used for assessing executive functioning. Further research is needed to better distinguish certain sports via their cognitive demands and analyze the quality of sport involvement additional to training hours.

6. Abbreviation Index

ADQ	Athletic development questionnaire
AE	Age episode
CEST	Computerized explorative sorting test
CF	Cognitive flexibility
DF	D-KEFS Design Fluency Test
D-KEFS	Delis Kaplan Executive Function System
EF	Executive functions
FT	Flanker test
FTS	Flanker test switching (complex Flanker)
INH	Inhibition
Inter	Interceptive sports
MSP	Main sport
RT	Reaction time
Stat	Static sports
Strat	Strategic sports
TI	Total involvement
TM Inv	Total music involvement
TMT	D-KEFS Trail Making Test
TSI	Total sport involvement
WM	Working memory

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Table of tables

Supplemental Materials

Athletic development questionnaire (ADQ) in the orginal german version.

FRAGEBOGEN SPORTLICHE ENTWICKLUNG

Code:		
Testdatum:		
Geschlecht:		
Geburtsdatum:		
Höchste abgeschlossene Ausbildung:		
	Pflichtschule (Polytechnikum)	[ ]
	Matura	[ ]
	laufendes Studium	[ ]
	Bachelor (Universität, FH, Kolleg)	[ ]
	Master (Universität, FH, Kolleg)	[ ]
Schultyp (Oberstufe) HTL, kreativer Zweig, usw.		
Studienrichtung (wenn relevant) Wirtschaft, Sport, usw.		

In diesem Fragebogen versuchen wir deinen sportlichen und persönlichen Werdegang/Lebenslauf abzubilden.

Im folgenden Teil geht es um deine Hauptsportart.

Momentane Hauptsportart:			
Position / Disziplin in der Sportart: z.B. Stürmer oder 400m Läufer			
Höchste erreichte Leistungsklasse in der momentanen Hauptsportart:			Nachwuchslevel
	Unorganisiert	[ ]	[ ]
	Schulsport	[ ]	[ ]
	Regional (Verein)	[ ]	[ ]
	National (Verein - Oberste Liga)	[ ]	[ ]
	International	[ ]	[ ]
	Top 10 der Welt	[ ]	[ ]
Anzahl der Jahre in höchster Leistungsklasse: (ohne Nachwuchs)			

Teilnahmen an Europameisterschaft (EM)	(Anzahl)	(Nachwuchs)
Beste Platzierung bei EM		
Teilnahmen an Weltmeisterschaft (WM)	(Anzahl)	(Nachwuchs)
Beste Platzierung bei WM		
Teilnahmen an Olympischen Spielen (OS)	(Anzahl)	
Beste Platzierung bei OS		

Dieser Teil des Fragebogens soll uns Aufschluss darüber geben welche Lebensereignisse und Entwicklungsepisoden in deinem Leben Einfluss auf deine kognitiven Fähigkeiten haben. Unsere Studie ist nur so genau wie die Informationen die du uns gibst. Bitte versuche dich deshalb genau zu erinnern und die Fragen so gut wie möglich und ehrlich zu beantworten.

Hast du dich jemals **intensiv** musikalisch betätigt? (Singen, Instrument gelernt) *Gelegentliches Singen unter der Dusche zählt nicht dazu.*	[ ] JA [ ] NEIN
Wenn JA: Welche musikalischen Tätigkeiten? (Mehrfachnennung möglich)	
Wie alt warst du als du damit begonnen hast?	
Wie viele Jahre hast du dich **intensiv** damit beschäftigt?	
Wie viele **Stunden pro Woche** hast du dich in dieser Zeit damit beschäftigt? (ca.)	

Hast du dich jemals **intensiv** künstlerisch/tänzerisch betätigt? (Malen, Zeichnen, Fotografie, Film, Schauspiel, Hip-Hop Tanz, Klassischer Tanz)	[ ] JA [ ] NEIN
Wenn JA: Welche Tätigkeiten? (Mehrfachnennung möglich)	
Wie alt warst du als du dich das erste Mal damit befasst hast?	
Wie viele Jahre hast du dich **intensiv** damit beschäftigt?	
Wie viele **Stunden pro Woche** hast du dich in dieser Zeit damit beschäftig? (ca.)	

Wie viele Jahre hast du dich intensiv mit Medien (Videoanlyse, TV,…) beschäftigt, welche für deine **Sportart relevant** sind?	
Wie viele **Stunden pro Woche** hast du dich in dieser Zeit damit beschäftigt? (ca.)	

Wie viele Jahre hast du dich **intensiv** mit Videospielen beschäftigt?	
Welche Art von Video-spielen (z.B. Ego-Shooter, Strategiespiel, Sportspiel)	
Wie viele Stunden pro Woche hast du dich in dieser Zeit damit beschäftigt? (ca.)	
Wie viele Jahre hast du dich **intensiv** mit Videospielen beschäftigt, welche für deine **Sportart relevant** sind.	
Wie viele **Stunden pro Woche** hast du dich in dieser Zeit damit beschäftigt? (ca.)	

TEIL 2

1) Versuche dich an alle Sportarten zu erinnern die du während deiner Kindheit / Jugend bis jetzt, regelmäßig betrieben hast (mehr als ~3-6 Monate) -> (orange Spalte)
(Hauptsportart soll an erster Stelle stehen)

2) Nun fülle für jede pro Sportart, die Spalten für das erreichte Leistungslevel aus -> (grüne Spalten)

	Sportart	Leistungslevel		
		*Höchste erreichte Leistungsklasse	im Alter von	Anzahl aktiver Jahre in dieser Leistungsklasse
1		________	________	________
2				
3				
4				
5				
6				
7				
8				
9				
10				

*Höchste erreichte Leistungsklasse:

- **U** = Unorganisiert
- **S** = Schulsport
- **R** = Regional (Verein)
- **N** = National (Verein - Oberste Liga)
- **I** = International
- **T** = Top10 der Welt

3) Wann hast du mit <Sportart1> begonnen. **(erste Altersstufe einfüllen) -> Graue Spalten**
Wie lange bist du auf diesem Leistungslevel geblieben **(zweite Altersstufe einfüllen)**

Wieviel Stunden pro Woche hast du dich aktiv mit der Sportart beschäftigt haben
(Stunden pro Woche – h/w)

Wie viele Monate im Jahr hast du den Sport aktiv ausgeübt
(Monate pro Jahr – m/y)

Wie sieht es mit den nachfolgenden Phasen in deinem Leben aus, in denen du diesen Sport betrieben haben.

(Proband soll Altersepisoden von der Kindheit bis heute benennen in denen der Sport ausgeführt wurde.
Episoden zeichnen sich durch selbe Intensität/Umfang aus.
- z.B. U14-Schwimmverein von 12-14, 3mal pro Woche Training zu je 2 Stunden, 10 Monate im Jahr)

Sportart abschließen dann selbes Prozedere bei <Sportart2> - usw.

	Sportart ↓	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
1																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
2																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
3																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
4																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
5																					

	Sportart ↓	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y	h/w	m/y
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
6																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
7																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
8																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
9																					
	Altersstufen →	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___	___ -	___
10																					