Self-Regulation and (Pre-) Academic Performance of Children and Young Adults in Germany and Iran

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Abstract

Self-regulation is a multidimensional construct that is defined as the ability to control thoughts, emotions, and behaviors and is positively related to academic achievement. Moreover, self-regulation is context-sensitive, suggesting that self-regulation abilities displayed by individuals might differ across different contexts. Germany and Iran provide two different contexts with distinct cultural characteristics that may affect self-regulation. In addition, up to this point, self-regulation has been mainly studied in Western countries with similar cultural contexts and there is a lack of research exploring self-regulation and its associations with academic performance in non-Western countries. Hence, the present dissertation investigated self-regulation and its association with (pre)academic performance in Germany and Iran with the aim of contributing to the better understanding of the context-sensitivity of self-regulation.

The development of self-regulation in college students as young adults is deeply embedded in the context in which they grew up, besides they are yet engaged in education and academic performance. However, although the relation of self-regulation and academic performance is well established for children, studies investigating this relationship in adults are rather scarce, hence requiring further research. Accordingly, in the first step, *Study 1* examined the relation of different aspects of self-regulation and mathematics performance in young adults. In the second step, *Study 2* compared the relationship between self-regulation and mathematics performance in young adults in two different countries (i.e., Germany and Iran). Therefore, *Study 1* and *Study 2* are best considered in conjunction.

Furthermore, the results of longitudinal studies in Western countries revealed that academic performance can be predicted by a child's self-regulation abilities at preschool age. Considering dissimilar effects of different contexts on the development of self-regulation, these results suggest that there might be differences between German and Iranian children at preschool age with respect to self-regulation abilities, which could influence their academic performance in the future. Accordingly, in the third step, *Study 3* investigated self-regulation abilities of German and Iranian children at preschool age before the start of their formal education.

Study 1 aimed to investigate the relationship between self-regulation and mathematics performance in young adults. In *Study 1*, different aspects of self-regulation and mathematics performance were tested in 40 undergraduate German students aged between 19 and 21, of

whom 33 were female. The findings showed that behavioral self-regulation did not predict mathematics performance, however, self-control, as an aspect of self-regulation, had a significant positive relationship with the mathematics performance. The results suggested that the college students with greater self-control abilities might have a greater ability to concentrate on the task and suppress unwanted thoughts or distracting information, and hence responded faster to the mathematic problems. Altogether, the findings demonstrated that the previously discovered positive relationship between self-control and mathematics performance in children is also valid in young adults.

Study 2 aimed to investigate the relationship between self-regulation and mathematics performance in young adults in two different countries (Germany and Iran). Self-regulation and mathematics performance were assessed in 44 Iranian college students and the results were compared with *Study 1,* which examined the same relationship in German college students. Self-regulation was assessed by the same measure used to assess self-control, as an aspect of self-regulation, in *Study 1*. Mathematics performance was measured by the same mathematics task used in *Study 1*. Moreover, the field of study of the students was also considered in this study. The findings of this study showed that self-regulation predicted mathematics performance only in German students and not in Iranian students. However, when the field of study was taken into account for Iranian students, self-regulation also predicted mathematics performance in the subgroup of Iranian students studying Human Sciences. Moreover, the relationship between self-regulation and mathematics performance in German students did not differ significantly from the whole Iranian group nor from the Iranian students of Human Sciences. In sum, the main results indicated that the relationship between self-regulation and mathematics performance is similar between German and Iranian college students when the effect of the field of study is considered.

Study 3 aimed to investigate the self-regulation abilities of German and Iranian preschool children in a delay of gratification task. Self-regulation ability was assessed in 100 Iranian and 48 German preschool children. Self-regulation ability was operationalized both as performance and strategies (i.e., focusing, withholding, distracting) used by children in a delay of gratification paradigm (Mischel, 1989). Children's behaviors while performing a delay of gratification task were video recorded and rated later with respect to the strategies that direct attention towards a reward and away from it. The results showed that German children waited longer than their Iranian peers in the delay of gratification task. Focusing strategies that directed attention towards

the reward undermined the performance in the delay of gratification task in German but not Iranian children. Moreover, German children used more withholding strategies than their Iranian peers to stop themselves from touching the reward. These results suggest that self-regulation abilities in children might vary between different countries at preschool age.

Altogether, these findings provide empirical evidence for the acknowledgment of the context-sensitivity of self-regulation, which has so far been little investigated. The results showed that self-regulation abilities differed between German and Iranian preschool children. However, the association between self-regulation and mathematics performance of young adults was similar in these countries when the field of study was taken into account.

1. GENERAL INTRODUCTION

Self-regulation is crucial for various aspects of everyday life such as inhibiting undesired behaviors, pursuing long-term goals, learning, and managing emotions at all ages. Self-regulation is a multidimensional construct that can be defined as the ability to control thoughts, emotions, and behaviors (e.g., Blair & Ursache, 2011; Calkins, 2007). The importance of self-regulation abilities for children's social development and academic performance has been highlighted by many previous studies (e.g., Blair & Razza, 2007; Duckworth & Carlson, 2013; Jaramillo, Rendón, Muñoz, Weis, & Trommsdorff, 2017; Weis, Trommsdorff, & Muñoz, 2016). For instance, poor self-regulation abilities at preschool age has been shown to be associated with facing peer rejection and later academic difficulties (e.g., Blair, 2002; McClelland & Tominey, 2011). It has also been shown that self-regulation abilities are closely associated with academic performance in educational settings, suggesting a positive relationship between the ability to self-regulate and academic achievements (e.g., McClelland & Cameron, 2011). From a lifespan perspective, self-regulation has lifelong importance as it is related to life satisfaction, physical health, and overall quality of life (Moffit et al., 2013).

Recent studies have revealed that self-regulation is context-sensitive (e.g., Heikamp, Trommsdorff, & Fäsche, 2013; Lamm et al., 2018; von Suchodoletz & Larsen, 2015; see also the review by Jaramillo et al., 2017), suggesting that the amount as well as the type of self-regulation ability can be influenced by the cultural context. For instance, it has been shown that the self-regulatory strategies used by German preschool children to resist temptation differ from the strategies employed by Cameroonian preschool children in the same situation (Lamm et al., 2018). In another example, in the educational setting, results of a longitudinal study investigating the application of self-regulatory strategies, revealed that some of the self-regulatory strategies used by Italian students did not predict academic achievement as they did in American students (Nota, Soresi, & Zimmerman, 2004). Different cultural contexts can influence the development of self-regulation, depending on the accentuation of individual or group goals (i.e., independence- or interdependence-orientation). For instance, the findings of a cross-cultural study investigating self-regulation abilities in German and Cameroonian preschool children indicated that independence-oriented context prevailed in Germany and interdependence-

oriented context which is dominant in Cameroon influenced developmental patterns of self-regulation (Lamm et al., 2018): self-regulation in German children was motivated by individual goals, while Cameroonian children, regulated their behaviors to fulfill their parents' expectations. Therefore, it seems that self-regulation abilities as well as their associations with academic performance might vary across different cultural contexts (e.g., independence- vs. interdependence-oriented contexts). However, empirical studies on self-regulation abilities in different cultural contexts are scarce (Trommsdorff, 2009) and even less is known about the relationship between self-regulation and academic achievement across different countries.

Furthermore, most participants in psychological studies consist of above-average highly educated people from Western, educated, industrialized, rich and democratic countries (WEIRD; e.g., North America, Northern and Western European countries; Henrich, Heine, & Norenzayan, 2010) that represent only 12% of the world population (Henrich et al., 2010; Arnett, 2008). This has raised concerns about the generalizability of many psychological research findings, in general, as they are limited to relatively similar cultural contexts, and thus, cannot provide a complete picture of the variability of human thoughts, feelings and behaviors. This concern is particularly important considering the extent to which contexts can influence the development of self-regulation (Heikamp et al., 2013; Trommsdorff, 2012; Trommsdorff & Heikamp, 2013).

Therefore, the present dissertation aims to examine the association between self-regulation and academic performance between two different contexts (Germany vs. Iran) in young adults and further investigate self-regulation abilities at preschool age in these countries. Germany has an independence-oriented context (Hofstede, 1984; Keller & Kärtner, 2013; Tõugu, et al., 2018) and Iran is representative of an interdependence-oriented context according to the literature (Hofstede, 1984). Hence, Germany and Iran provide two different cultural contexts that may affect self-regulation.

The present dissertation is subdivided into three main parts. Following this general introduction, Chapter 2 first provides insights into the concept of self-regulation and then illuminates different methods for measuring this construct with special emphasize on methods used in the present dissertation. It then discusses the importance of self-regulation for academic performance and highlights the context-sensitivity of self-regulation. The second part of the same chapter focuses on the self-regulation associations with cultural context. Accordingly, it provides an overview on the concept of culture and then with reference to different cultural

models, discusses the role of cultural contexts for the development of self-regulation. Later, it outlines some cultural differences between the countries that were examined in the present dissertation (i.e., Germany and Iran). This Chapter ends with the presentation of the main research questions addressed in the present dissertation. Chapter 3 presents the studies incorporated in the present dissertation. Lastly, Chapter 4 discusses how the results presented in these studies may contribute to the research aims of the present dissertation.

2. THEORETICAL BACKGROUND

2.1. Self-Regulation

The ability to self-regulate is associated with various positive outcomes in life (e.g., Moffit et al., 2013; Tangney, Baumeister, & Boone, 2004). People with greater self-regulation abilities have better academic performance, more stable couple relationships, tend to be less aggressive, report fewer psychological problems (e.g., depression) and are less likely to commit crimes than people with less self-regulation abilities (Baumeister & Alquist, 2009; Tangney et al., 2004). Self-regulation is a multidimensional construct including emotional and cognitive aspects. The aspects that were investigated in the present dissertation (e.g., self-control) will be discussed in this chapter.

Self-regulation can be required in many different situations and contexts. For instance, when a young child follows his/her mother's warning to not touch a hot stove at home, a preschool child waits for his/her turn in a game in a kindergarten, a schoolchild completes a multi-step mathematics problem at school, or a college student studies for a final exam in the library instead of hanging out with friends. These are all relevant illustrations of self-regulation application in different situations and contexts. The connection between all these examples is the ability to regulate behavior in order to achieve a desired goal or adapt to the demands of a situation. In order to better understand self-regulation, the following will provide an overview on the concept of self-regulation.

2.1.1. Conceptualization of Self-Regulation

A precise definition of self-regulation is difficult, since neither a uniform term nor a universally accepted definition has been established in the literature (Heikamp, 2014; Karoly, Boekaerts, & Maes, 2005). A broad definition of self-regulation includes the ability to control one's own thoughts, emotions, and behaviors (e.g., Blair & Ursache, 2011; Calkins, 2007). Some researchers have also defined self-regulation as an ability that enables individuals to exert goal-directed behaviors in accordance with individual goals or societal rules. For example: "Self-regulation refers to the capacity of organisms (here, human beings) to override and alter their responses. It is the process by which people attempt to constrain unwanted urges in order to gain

control of the incipient response. Regulation means change, especially change to bring behavior (or other states) into line with some standard such as an ideal or goal. Changing one's behavior so as to follow rules, match ideals, or pursue goals is thus a (very useful) form of self-regulation" (Baumeister & Vohs, 2007, p. 116). Self-regulation can be understood here as the ability to alter one's behavior and control the unwanted behaviors through regulatory processes to bring about a state that is in line with desired individual goals or social norms.

Carver and Scheier (2011) pointed out that some authors make an explicit distinction between self-regulation and *self-control*. However, other researchers (e.g., Baumeister & Alquist, 2009; Baumeister & Vohs, 2003) have used the terms self-regulation and self-control interchangeably and defined both as the ability to override or alter undesired behaviors in order to achieve a desired goal. In the present dissertation, self-regulation refers to a multidimensional construct that encompasses the processes of controlling one's behavior, emotions, and thoughts and self-control serves as the subset of self-regulation that describes voluntary processes related to overriding undesirable behaviors and impulse control (i.e. control of unwanted reactions).

The ability to self-regulate is understood both as a personal disposition or trait (i.e. stable characteristic) and as a state (i.e., situation-dependent behavior; e.g., Baumeister & Heatherton, 1996). For instance, self-regulation when operationalized as the ability to delay the gratification (i.e., the ability to forgo an immediate small reward in favor of a larger one in the future) proved to be a relatively stable characteristic at pre-school age that predicted inter-individual differences in self-regulation abilities even 40 years later (Casey et al., 2011). At the same time, preschool children might be more capable of resisting the temptation to eat cookies at preschool than at dinner table at home.

Recently, McClelland and colleagues (2015) proposed a perspective on understanding self-regulation based on the notion of relational developmental systems (Overton, 2013). In a relational developmental system, development is considered as a dynamic and bidirectional process of person-context relations. This means that there are reciprocal interactions between individuals and their context (i.e., here characterized by the ecological environment throughout the life span) during development. The concept of self-regulation in this perspective implies a person who manipulates his or her environment and the environment that provides conditions which similarly regulate the person's behaviors (McClelland et al., 2015). For example, it has been shown that there are reciprocal interactions between children's self-regulation abilities and

parenting behaviors which means that one can influence the other over time (e.g., Calkins, 2007; Lengua & Kovacs, 2005). This perspective suggests that empirical research on self-regulation should consider context as an integral part of the ability to self-regulate. The same approach towards self-regulation was adopted in the present dissertation as context was taken into account when investigating self-regulation and its correlates.

2.1.2. Self-Regulation Measures

There is diversity in how self-regulation is operationalized in different research studies. The two primary methods of measuring self-regulation are via questionnaires and performance-based tasks. Evidence on the convergent validity (i.e., significant correlations between different instruments designed to assess a common construct) among different self-regulation measures including questionnaires and performance-based tasks demonstrated moderate convergence (r_{random} = .27 [95% CI = .24, .30]; r_{fixed} = .34 [.33, .35], k = 282 samples, 564 participants; Duckworth & Kern, 2011). In the following, these two most common approaches for assessing self-regulation will be described with special emphasis on the specific measures that were used in the present dissertation.

Questionnaires on self-regulation have been shown to predict academic achievement (Duckworth, Tsukayama, & May, 2010), physical health (Moffitt et al., 2011; Tsukayama, Toomey, Faith, & Duckworth, 2010), and criminal activity in adulthood (Moffitt et al., 2011). They include self-reports (reported by the person concerned) and informant-reports (reported by caregivers or a third party like teacher). Generally, questionnaires require the ability to read the questions or items that need to be answered, and therefore, are not readily administered to preschool children. Self-reports are among the prevalent methods of measuring self-regulation abilities in adults. They can collect information from many reporters in a short time, however, the information ratings can be influenced by reporter subjectivity and bias (Bowling, 2005). For instance, a person's feelings at the time they filled out the questionnaire can influence their answers.

Furthermore, self-report questionnaires are heterogonous in the aspects of self-regulation assessed. For example, the Impulsiveness Scale (Eysenck, Easton, & Pearson, 1984) merely contains items about doing and saying things without thinking, however, the Self-Control Scale (SCS; Tangney et al., 2004) provides more information on self-control and includes more

extensive items such as acting without thinking about the alternatives, resisting temptations, and the ability to exert a goal-directed behavior in order to achieve a long-term goal. Moreover, high validity and reliability of BCSC was reported in earlier studies (e.g., Rauch, Gawrilow, Schermelleh-Engel, & Schmitt, 2014). Hence, the brief version of the SCS (BSCS; Tangney et al., 2004) was used in the present dissertation to assess self-control as an aspect of self-regulation. Since, the scores on the BSCS showed a significant association with mathematics performance of German college students in the first study (*Study 1*), it was further used in the second study (*Study 2*) to assess self-regulation in Iranian college students. However, self-reports are not applicable for preschool children, thus, a performance-based task was used to assess self-regulation abilities in preschool children in *Study 3*.

Performance-based tasks assess self-regulation abilities by presenting participants with various computerized stimuli (e.g., participants are asked to refrain from pushing a button when a non-target stimulus appears on a computer screen), choices and conflicts (e.g., participants are instructed that they have to refrain from immediately eating a single marshmallow in order to obtain two marshmallows later) or hypothetical scenarios such as asking participants whether they hypothetically would opt to earn a small payout immediately or a larger financial payout in the future. One of the well-established performance-based tasks for assessing self-regulation abilities in children is in the paradigm of *delay of gratification* which was used in the present dissertation (*Study 3*). Both delay of gratification task and BSCS questionnaire measure self-control aspect of the self-regulation. Delay of gratification paradigm will be explained in more detail in the following section.

Delay of Gratification

Delay of gratification is an essential aspect of volitional self-regulation. It refers to the ability to postpone a smaller reward for the sake of a larger but delayed reward (Mischel, 1989; for the summary, see Mischel, 2014). Many decisions children make in their everyday life are comparable to a delay of gratification situation, such as interrupting the teacher versus waiting to be called to answer or doing homework versus going out with friends. These situations require the ability to inhibit the prepotent responses (e.g., interrupting the teacher) or resisting the temptation (e.g., hanging out with friends) in favor of a long-term goal (e.g., academic achievement) in the future. Moreover, the strategies used by children to inhibit prepotent

responses or overcome the immediate temptations can influence their ability to delay gratifications and may help them deal with situations later in life, which require self-regulation (e.g., Mischel et al., 2011). Therefore, the delay of gratification paradigm allows not only for the investigation of the self-regulation ability in children but also the factors which can influence the ability to delay gratification which will be discussed later.

There are two well-established methods for assessing the ability to delay gratification: the *choice task* and the *waiting task*. In the choice task, the participants are asked to choose between a small reward immediately and a larger or more valuable one at a later specified time (e.g., three days later). In the waiting task, the participants, usually children, are asked to choose between a small reward immediately and a larger reward later (e.g., until the experimenter returns to the room). Thus, if they choose the larger reward, they must wait until the experimenter returns to the room. Furthermore, the participants are also told that they can stop waiting by ringing a bell, however, by doing so they will get only the smaller reward (Metcalfe & Mischel, 1999; Mischel, 2014). Therefore, in the waiting task, the participants are able to change their decisions at any time during the entire waiting period (i.e., self-imposed waiting). Consequently, the participants continually experience a conflict situation in which they have to choose between ending the waiting period and resisting the temptation to ring the bell. In contrast, in the choice task, once the participants choose whether they want to wait or not, their decision cannot be cancelled and they either receive the smaller reward immediately or have to wait until the end of the specified time.

Therefore, it seems that the waiting task is more satisfactory for assessing self-regulation in preschool children than the choice task, which includes a hypothetical delay (e.g., receiving five euros immediately or ten euros in two weeks) rather than an actual delay (e.g., receiving one cookie right now or two cookies when the experimenter returns to the room), in assessing self-regulation abilities in preschool children (Neubauer, Gawrilow & Hasselhorn, 2012). Moreover, performance in the waiting task at preschool age has been shown to predict academic achievement and social competence ten years later (Shoda, et al., 1990). For example, preschool children who had waited longer in the waiting task achieved higher Scholastic Aptitude Test scores and were rated as more socially competent by their parents in their adolescence than those who had a waited a shorter time. The predictive power of performance in the delay of

gratification task supports the relevance of this paradigm for assessing self-regulation in preschool children.

The factors facilitating children's performance in the waiting task have been investigated. One crucial factor influencing performance seems to be the strategies used by children during the waiting time. Previous studies revealed that children waited longer if they could not see the reward (i.e., when the reward was physically covered) during the waiting period or if they were instructed to think about something other than the reward (Mischel, 1996; Mischel & Baker, 1975; Mischel, Ebbesen, & Zeiss, 1972; Mischel & Moore, 1973; for a summary, see Mischel, 2014). It has been shown that strategies that direct attention away from the reward (e.g., turn away from the reward) are associated with longer waiting, while, strategies that draw attention towards the reward (e.g., touching the reward) interfere with waiting (e.g., Eigsti et al., 2006; Manfra, Davis, Ducenne, & Winsler, 2014; Neuenschwander & Blair, 2017; Rodriguez, Mischel, & Shoda, 1989; Vaughn, Kopp, Krakow, Johnson, & Schwartz, 1986). To sum up, the strategies used by children to distract themselves from the reward seem to facilitate waiting, whereas focusing strategies that draw attention towards the reward hamper waiting in the waiting task.

However, performance and behavioral strategies of preschool children in the waiting task have been mainly investigated in Western countries and only once explored cross-culturally. The results of a cross-cultural study between Cameroon and Germany showed that both performance and behavioral strategies of children in the waiting task differed between Cameroonian and German preschool children (Lamm et al., 2018). Therefore, it seems that contexts might influence performance and self-regulatory strategies used by children in the waiting task. Accordingly, the associations of context with performance and behavioral strategies used by children in the waiting task was explored in the present dissertation (*Study 3*).

Furthermore, it has been shown that performance in the delay of gratification task at preschool age is related to later academic achievements in adolescence (e.g., Shoda et al., 1990). The relationship between self-regulation abilities of children and their academic performance is well-established in the literature. The following is, therefore, an overview of the associations between self-regulation abilities and academic performance and the mechanisms underlying these associations.

2.1.3. Association between Self-Regulation and Academic Performance

Self-regulation includes different abilities such as maintaining attention or inhibiting undesired behaviors in learning situations, which lay an important foundation for successful academic performance (McClelland & Cameron, 2011). Previous studies revealed that children who are able to effectively manage their thoughts, feelings, and behaviors have better academic performance than students without adequate self-regulatory abilities (e.g., Blair & Diamond, 2008; Frazier et al. 2007; McClelland, Ponitz, Messersmith, & Tominey, 2010; Zentall, 2007). Furthermore, the results of longitudinal studies demonstrated that at preschool age, self-regulation abilities can predict later academic outcomes (e.g., Shoda et al., 1990; Watts, Duncan, & Quan, 2018). In the same vein, children who enter kindergarten without adequate self-regulatory abilities are at a greater risk for later academic difficulty (Blair, 2002; McClelland, Morrison, & Holmes, 2000). Self-regulation can contribute to academic performance, particularly mathematics performance, through various mechanisms such as executive functions.

Executive Functions

Executive functions represent the higher-level cognitive processing that support successful self-regulation (Hofmann, Schmeichel, & Baddeley, 2012). Executive functions serves a top-down cognitive mechanisms of self-regulation and the overlap between different aspects of executive functions and self-regulation is to the extent that sometimes they were used interchangeably in the literature. Executive functions include voluntary top-down cognitive processes consisting of three core components: *inhibition*, *shifting*, and updating *working memory* (WM; Miyake et al., 2000). Some researchers also consider planning and the regulation of attention (i.e., vigilance) as executive functions (e.g., Halperin, Trampush, Miller, Marks, & Newcorn, 2008; Toplak, Bucciarelli, Jain, & Tannock, 2008). Inhibition serves to deliberately inhibit prepotent or automatic responses and also includes resistance to distractors (Diamond, 2013; Miyake et al., 2000). Shifting refers to flexible shifting between different tasks or mental sets (Miyake et al., 2000). Updating WM can be defined as a system of storage undergoing constant monitoring and manipulation of recent visuospatial and verbal information (Baddeley, 2012; Baddeley & Hitch, 1974). Furthermore, recent research on the functions of different regions of prefrontal cortex suggests *hot* and *cool* aspects of executive functions (Zelazo & Müller, 2002). Hot aspect is associated with regulating emotions and cool aspect is related to cognitive processing. Both hot and cool executive functions allow students to control their

behaviors, maintain attention, remember instructions, and complete tasks at school. These functions play an important role in learning processes not only during school years but also in the early years of life. For instance, previous studies revealed that executive functions are associated with early academic achievement, such as early mathematical and verbal skills (e.g., Allan, Hume, Allan, Farrington, & Lonigan, 2014; Blair & Razza, 2007). Furthermore, it has been shown that executive functions at preschool age can predict later academic outcomes (Blair & Razza, 2007; Preßler, Könen, Hasselhorn, & Krajewski, 2014). Therefore, it seems that executive functions play a crucial role in (pre-) academic skills.

The components of executive functions are considered as strongly inter-correlated but separable (Diamond, 2006; Garon et al., 2008; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000) and contribute to academic performance through different mechanisms. For instance, inhibition contributes to the ignoring of irrelevant and distracting thoughts while learning new material at school. Another example is that WM supports arithmetic calculations through its role in concurrent storage and processing of digits (e.g., Diamond, 2006; Peng, Namkung, Barnes, & Sun, 2016; Swanson & Jerman, 2006). There is strong evidence for the contribution of executive functions to mathematics performance in particular (e.g., Blair & Razza, 2007; Clark, Pritchard, & Woodward, 2010; Cragg & Gilmore, 2014; Lee, Ng, & Ng, 2009). For instance, it has been suggested that in multiplication problem solving, WM is involved in retrieving answers from long-term memory and computation processing (e.g., Mabbott & Bisanz, 2003; Soltanlou et al., 2015).

Despite the evidence on the strong associations between executive functions and academic performance (e.g., Blair & Razza, 2007; McClelland et al., 2007; von Suchodoletz et al., 2013; Wanless et al., 2011), it remains unclear how different aspects of self-regulation are associated with academic performance across various contexts. Recent studies have showed that self-regulation is context-sensitive (e.g., von Suchodoletz, Uka, & Larsen, 2015; see also the review by Jaramillo et al., 2017). The context-sensitivity of self-regulation abilities will be explained in more detail in the following section.

2.1.4. Self-Regulation Across Different Contexts

Recent studies investigating self-regulation suggest that an individual's self-regulation abilities might be context-sensitive (e.g., McClelland et al., 2010; Toplak, West, & Stanovich,

2013; von Suchodoletz & Larsen, 2015). This means that contexts (e.g., family, school, culture) might have an influence on the amount as well as the type of self-regulation abilities displayed by individuals (e.g., Perels, Gürtler, & Schmitz, 2005; Schunk, 2005). For instance, self-regulation abilities measured under standardized conditions in the laboratory might differ from self-regulatory abilities observed in everyday life in response to the different demands of each context experienced (e.g., Wiebe, Epsy, & Charak, 2008).

In the early years of life, contexts such as family or kindergarten may have different demands and expectations of children's ability to regulate their behaviors and at the same time provide different amounts of support for their self-regulation abilities (Graziano, Reavis, Keane, & Clakins, 2007). For example, in the family context, it has been shown that external instructions provided by parents are usually positively related to the child's self-regulation abilities (e.g., Bernier, Carlson, & Whipple, 2010). On the other hand, classroom contexts, generally, lack extensive external control over each individual child and, thus, children are expected to complete assignments independently (Graziano et al., 2007). Therefore, the demands of each context as well as the goals of individuals in regard to regulating their behaviors in a specific context compared to their goals in another context might vary and lead to different self-regulated behaviors.

A framework proposed by Duncan and Miller (2002) suggested that neural processes involved in self-regulation abilities (e.g., exerting voluntary goal-directed behaviors) adapt to context in a way that allows them to fulfill context-specific behavioral demands. Therefore, self-regulatory abilities observed in one context might be different from those observed in response to the demands of other different contexts. In the same vein, cultural contexts can influence the development of self-regulation abilities. For instance, a cross-cultural study between Korea, China, and Japan suggested that cognitive aspects of self-regulation are associated with social experiences and cultural contexts (Lewis, Koyasu, Oh, Ogawa, Short, & Huang, 2009). The authors argued that patterns of self-regulation abilities in Korea, China, and Japan differ from those observed in Western countries, which might be due to different parental demands and expectations in regards to the control of behavior in these countries.

Altogether, adopting a context-sensitive approach and perspective on self-regulation can help to improve researchers' understanding of the underlying processes of self-regulation development across different contexts and diverse populations. There are few studies on self-

regulation in countries other than Western countries, in particular the United States, in the recent years, (e.g., Gestsdottir et al., 2014; Keller et al., 2004; Lamm et al., 2018; von Suchodoletz et al., 2015; Wanless et al., 2011), yet even less is known about self-regulatory processes across different cultural contexts. Hence, the present dissertation aimed to investigate self-regulation and its association with academic performance in two different countries (Germany and Iran) that represent two different cultural context.

2.2. Cultural Context

The following section defines the concept of culture and then provides an overview on different cultural models and their associations with self-regulation development. This is followed by a discussion of the existing findings on the cultural differences between Iran and Germany. The main focus of this section is on the role of different cultural contexts in the development of self-regulation abilities.

Definition of Culture

Culture is difficult to define and measure. In order to illustrate the difficulty of defining culture as a concept, one can refer to Kroeber and Kluckhohn (1952) who have gathered over 100 different definitions of the term culture (Heikamp, 2014). The present dissertation does not aim to comprehensively present the different conceptualizations of culture and its historical development. Nevertheless, the concept of culture is described in order to provide a basis for understanding the role of cultural contexts in the development of self-regulation abilities.

Difficulties in finding a uniform definition for the concept of culture are partly due to the fact that the concept of culture used in each academic discipline is strongly influenced by the research perspective (Heikamp, 2014). For instance, in Psychology, definitions mainly focus on experimental problem-solving strategies, habits and customs acquired through learning processes during development. Although there is no uniform definition, there is broad consensus that culture consists of practices, values, beliefs, and meanings shared by individuals within a particular group of people and can be transmitted through different time periods and generations (Triandis, 2007). Accordingly, culture develops on the basis of interactions between humans and their environment. Triandis (1996) distinguishes between material culture such as art and subjective culture such as values and beliefs. Subjective culture is one of the factors that can

influence how and why we behave certain ways and what we accept as good and desirable (Westby, 1993).

Furthermore, as difficult as it is to define culture, measuring this construct is also challenging. Culture cannot be limited exclusively to contextual framework, however, the approach of describing culture through grouping different cultural contexts (e.g., independent vs. interdependent), to some extent helps to reduce culture to a certain number of comparable and measurable variables to explain similarities or differences between various cultural contexts (Heikamp, 2014). This approach was adopted in the present dissertation for interpreting the results of empirical cross-cultural/national studies (i.e., *Study 2* and *Study 3)*, although different variables of cultural contexts were not directly measured in these studies. The following section provides an overview of the cultural models that address different cultural contexts and their influence on the development of self-regulation.

2.2.1. Different Cultural Contexts

Many researchers have used the approach of grouping cultural variations together for ease of comparison (Heikamp, 2014). Two of the most widely used grouping methods are individualism/collectivism (Triandis, 1996; Triandis, 1988) and independency/interdependency (Markus and Kitayama, 1991), which tackle the similar concepts. Individualistic cultures place emphasis on the needs of the individual over the needs of the group or community. In this type of culture, individuals are seen as independent and autonomous. Hence, behaviors often tend to be dictated by one's own attitudes and preferences rather than society. In contrast, in collectivist cultures characteristics like being self-sacrificing and dependable are of greater importance (Triandis, 1996).

The theoretical framework proposed by Markus and Kitayama (1991) includes independent and interdependent contexts. In the independent contexts, autonomy and an individual's freedom of decision is highly valued. In interdependent contexts, on the other hand, the attachment to other people and belonging to a group or community is emphasized. Accordingly, an independent context is associated with a person's goals, while an interdependent context is related to community goals. Since belonging to the group is essential in interdependent contexts, group goals (e.g., solidarity) take priority over a single person's goals: "In many domains of social life, one's opinions, abilities, and characteristics are assigned only secondary

roles – they must instead be constantly controlled and regulated to come to terms with the primary task of interdependence" (Markus & Kitayama, 1991, S. 227). For instance, the performance of American children of Asian and European origin aged 7 to 9 years was observed under different conditions (Iyengar & Lepper, 1999). In one condition, the children were allowed to select the task themselves (i.e., personal choice condition). In the second condition, the children were informed that their mothers had already selected the task (i.e., mom choice condition). Anglo-American children showed a high willingness to perform when they had the opportunity to choose freely the task they wanted to work on from various alternatives. For American children of Asian origin (e.g., Japan, China), the motivation to perform was higher if the mothers had decided on their behalf. Therefore, children from independence-oriented contexts preferred the situations that allowed them to select goals according to their individual preferences. Children from interdependence-oriented contexts, on the other hand, were more willing to accept their mothers' decisions and, therefore, were motivated to fulfill their mothers' expectations. This is in line with the concept of an independent context in which unwanted support or help can create a feeling of dependency that affects the experience of autonomy (e.g., Chirkov, Ryan, Kim, & Kaplan, 2003). In contrast, in the case of the interdependent context, individuals define themselves through their membership in a group and its associated roles and obligations (Heikamp, 2014).

The above-mentioned cultural grouping has been widely used in cross-cultural psychological research (e.g., Chen, 2015; Heikamp, 2014; Li, Wang, Wang, & Shi, 2010; Mesman et al., 2016; Tu, Lin, & Chang, 2011). The present dissertation also used the independent/interdependent distinction for interpretation of the results of *Study 2* and *Study 3*. However, some researchers have criticized the perspective in which cultural contexts are classified as either independent or interdependent saying these are simply opposite poles of one dimension (for a critique from a developmental psychological point of view see Raeff, 2010). For instance, a meta-analysis revealed within-society as well as cross-society variability in terms of independency and interdependency (Oyserman, Coon, & Kemmelmeier, 2002). However, the authors noted that the results for both independent and interdependent contexts depended mostly on the specific measures used for assessing them. Accordingly, due to the heterogeneity of cultural contexts, it seems that both independent and interdependent values coexist in a culture or on an individual level (Raeff, 2010). Therefore, independent and interdependent values might

differ in their relative strength in various aspects of everyday life as well as across different cultural contexts.

In sum, cultural contexts might differ in their relative accentuation of independent or interdependent values. This also means that independent or interdependent orientations can find expression in different culture-specific forms of thinking, feeling and acting (Killen & Wainryb, 2000). Therefore, the tendency to focus on independency or interdependency is an aspect of a culture that can influence on self-regulation abilities (Heikamp, 2014). The following explains the role of cultural contexts for the development of self-regulation abilities.

2.2.2. Association between Cultural Contexts and Self-Regulation

In independence-oriented contexts that tend to emphasize autonomy and independence, behavior is more oriented towards achieving individual goals that are in line with one's own desires and needs. In interdependence-oriented contexts, on the other hand, the need for solidarity and remaining a fit within the group are central motives for actions. Hence, behavior is more oriented towards fulfilling social obligations and meeting expectations (for the overview see also Heikamp, 2014 and Trommsdorff, 2009).

In the same line, in independence-oriented contexts, where individuality, independence and autonomy are highly valued, it seems meaningful to bring about changes in the environment (e.g., implementation of individual goals) in order to emphasize personal interests and abilities. Therefore, self-regulation in independence-oriented contexts is aimed at actively bringing about change in order to shape the environment according to individual needs. In interdependence-oriented contexts, on the other hand, social relationships have priority over individual needs. Individuals in interdependence-oriented contexts, therefore, make efforts to adapt their emotions and behaviors to the environment in order to maintain in harmony with the group (Heikamp, 2014). Hence, self-regulation in interdependence-oriented contexts aims at controlling one's own emotions and behaviors in accordance with the external environment (e.g., Rothbaum & Wang, 2011). For instance, in independence-oriented contexts (e.g., Canada), in which assertiveness and independence are highly valued, socially inhibited behaviors and feelings such as shyness can be interpreted as a lack of social competence. In one study, Canadian children received accepting behaviors from their mothers when they showed less inhibited behaviors in new unfamiliar situations (Chen et al., 1998). However, in China, where independence-oriented context

prevailed, socially inhibited behaviors in unfamiliar situations are more socially desirable and, therefore, positively reinforced by parents and culturally mediated educational goals and practices (Chen, Chen, Li, & Wang, 2009).

In another example, in Germany, an independence-oriented context, mothers showed more child-centered behaviors by addressing the cause of an emotional reaction and comforting the child than in Japan, where the interdependence-oriented context is dominant (Friedlmeier & Trommsdorff, 1999). In Japan, an expression of negative emotions is undesirable. Accordingly, Japanese mothers tried to support their children in regulating negative emotions by distracting their children through drawing their children's attention to the environment. Therefore, it seems that in order to behave in accordance with mothers' expectations and remain in harmony with the cultural context, 5-year-old Japanese girls showed less negative emotional reactions in frustration situations than German girls (Friedlmeier & Trommsdorff, 1999). These findings suggest that self-regulation abilities are promoted according to cultural contexts and children acquire behavioral patterns at an early age that enable them to successfully master the specific requirements of the cultural context (for an overview see Chen, 2010). The following provides an overview on the *Cultural Model of Agency and Self-Regulation* proposed by Trommsdorff (2009) to discuss the associations between cultural context and self-regulation in more details.

Cultural Model of Agency and Self-Regulation

In the Cultural Model of Agency and Self-Regulation, Trommsdorff (2009) referred to the concept of self, based on a cultural model of giving priority to independence or interdependence (Markus & Kitayama, 2003). She proposed that the development of self-regulation occurs in a cultural niche that conveys a specific cultural model of self, either focusing on independence or on interdependence. Accordingly, an *independent self-construal* is characterized by focusing on one's own abilities, preferences, goals, and desires (i.e., disjoint agency), whereas, *interdependent self-construal*, is characterized by a sense of belonging to the group and centering one's role and responsibilities in the group (i.e., conjoint agency; see Figure 1 for a graphical representation).

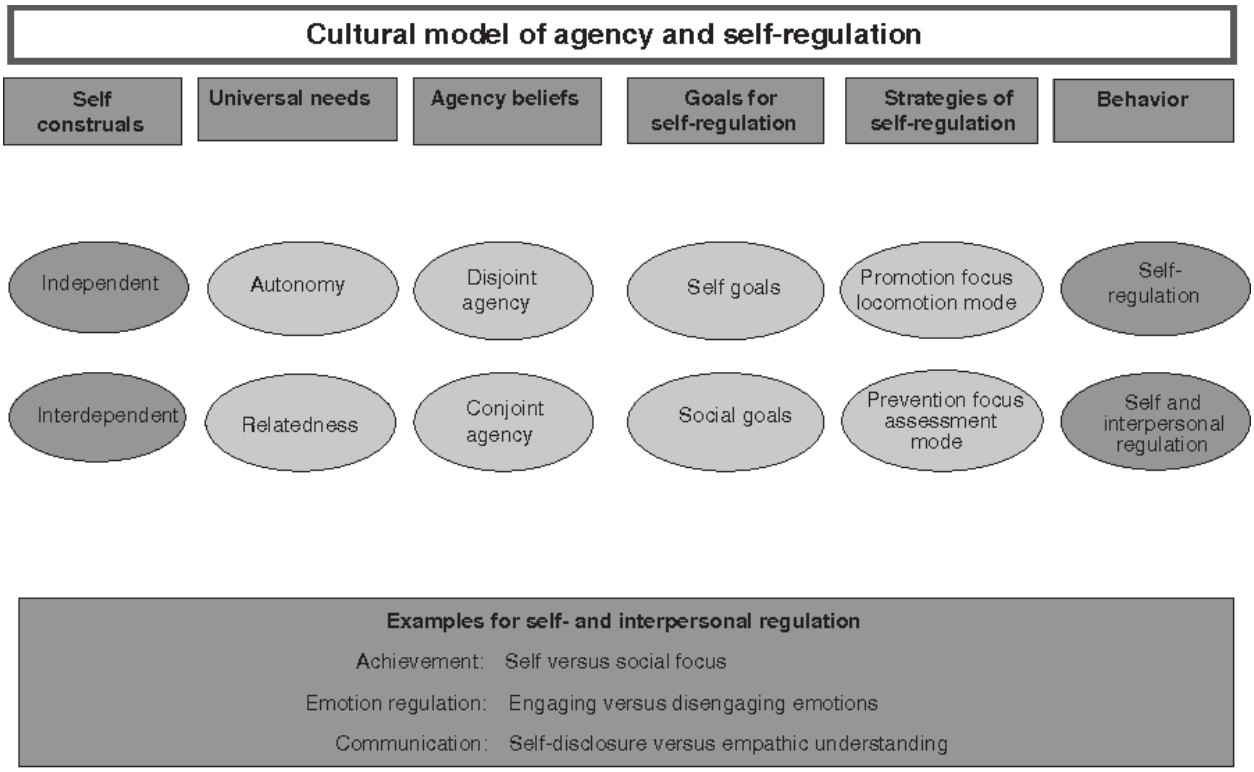

Figure 1. Cultural model of agency and self-regulation (taken from Trommsdorff, 2009).

In this regard, self-regulation can be considered as a motivated action in accordance with the dominant cultural model of self. In the case of the independent model of self, promoting self-regulation prevails and is associated with giving priority to autonomy and individual goals, whereas, in the case of the interdependent model of self, prevention of self-regulation is dominant and related to giving priority to relatedness (e.g., belief in belonging to the group) and group goals (see Figure 1). Therefore, based on this model, self-regulation includes efforts to inhibit or activate behaviors to achieve individual or group goals.

Furthermore, this model assumed that the dominant cultural values and the related cultural models (e.g., independence/interdependence) influence the socialization of children and their respective development of self-regulation abilities. Socialization processes include the process of internalizing the expectations of significant figures who are close to the child, like parents. Expectations of parents or other significant people in a children's life are in accordance with the cultural context. Accordingly, once expectations of significant others are internalized, a person can more easily adjust his or her goals and behaviors to be in line with the cultural context. Therefore, internalization of the expectations of significant others develops into a self-

regulatory system that is in accordance with the cultural context (Trommsdorff, 2009). This self-regulatory system that is in line with the cultural context contributes to a cultural fit and also explains how the development of self-regulation can be linked with cultural values and individual goals. Thus, the development of self-regulation can be seen as a process by which goals are achieved in line with the respective dominant cultural model. To sum up, the Cultural Model of Agency and Self-Regulation (Trommsdorff, 2009) proposed that the development of self-regulation might vary according to the cultural context in which the development of the individual is embedded. Therefore, studies investigating self-regulation should consider that the efforts of an individual to control emotions and behaviors to achieve goals are immersed in a cultural context that gives priority to prevailing values, goals, and outcomes. However, more empirical research is needed to test the Cultural Model of Agency and Self-Regulation, particularly in regards to the developmental processes linking culture and self-regulation abilities.

Cultural contexts including cultural values and practices have been described as developmental niches (Super and Harkness, 1986) that can mediate the influence of culture on the development of self-regulation in children. For instance, parenting behaviors as part of a cultural niche affect the development of self-regulation by reinforcing culturally valued behaviors of children (e.g., Super & Harkness, 1997). In this regard, Trommsdorff (2009) states that the expectations of significant figures who are close to children (e.g., parents) become an integral part of a child's value systems, which lead them to develop a self-regulation style that aims to fit into the culture to which they belong.

Parenting Behaviors across Different Cultural Contexts and Their Associations with Self-Regulation Development

With regard to a child's development of self-regulation abilities, it has been shown that self-regulation patterns sometimes reflect the history of parenting behaviors of caregivers (Calkins & Hill, 2007). For instance, parental control has been shown to be significantly associated with the development of a child's self-regulation abilities (e.g., Karreman, van Tuijl, van Aken, & Deković, 2006). The results of a meta-analysis of 41 studies demonstrated a significant positive relationship between parental control and self-regulation abilities of preschoolers, when self-regulation is characterized by compliance (Karreman et al., 2006).

Parenting behaviors are displayed in a cultural context. Cultural contexts, in which some goals and behaviors are valued, whereas others are considered undesirable. Therefore, parenting behaviors can influence a child's appraisal of their experiences in regulating their emotions and behaviors by reinforcing some behaviors and discouraging others in accordance with the cultural context (Díaz & Eisenberg, 2015; see Jaramillo et al, 2017 for the review). Furthermore, parents' expectations, influenced by cultural values, can also play an important role in the development of self-regulation abilities of children. More specifically, a child's motivation and ability to self-regulate are consistent with the culturally guided expectations of parents (Trommsdorff, 2009). For instance, two studies compared parenting behaviors of European American and Puerto Rican mothers of under 2-year-old children (Harwood, Schoelmerich, Schulze, & González, 1999; Carlson & Harwood, 2003). These studies found that European American mothers promoted autonomy of their children and expected them to behave in accordance with their personal desires, but Puerto Rican mothers expected their children to behave in accordance with their parental expectations and societal values. Moreover, in line with their parenting goals, European American mothers structured learning situations indirectly by offering suggestions and giving their children room to choose for themselves. Puerto Rican mothers, on the other hand, tended to use more authority to teach their children the way of behaving in accordance with what was expected.

In the same vein, in independence-oriented contexts in which autonomy is promoted, external rules and obligations set by parents might be understood as a way of coercive control that undermines self-regulation and an independent self. In contrast, in interdependence-oriented contexts in which fulfilling parents' expectations are emphasized, parents' controlling behavior might be perceived as a support for self-regulation (Jaramillo et al, 2017; Trommsdorff, 2009). For instance, while in the European American countries, warm and responsive parenting behaviors support emotion-regulation in children and adolescents, the promotion of emotional adjustment is achieved through restrictive parenting in the Asian and Latin American countries (e.g., Ang & Goh, 2006; Chao, 1994; Huang & Gove, 2015).

Therefore, parenting behaviors are related to cultural contexts and can affect the development of self-regulation abilities in children. Investigating parenting behaviors across various countries could help explain differences in self-regulation abilities of children in those countries. Hence, parenting behaviors are considered in the present dissertation (*Study 3*) to

examine whether they differ in Germany and Iran and to investigate their associations with the self-regulation abilities of children. Parenting behaviors are expected to differ between Germany and Iran as independence-oriented context prevails in Germany, while interdependence-oriented context is dominant in Iran. In the following section, some cultural differences between Iran and Germany are described with particular emphasis on the individualism/collectivism cultural model. However, describing detailed cultural differences between Iran and Germany is beyond the scope of the present dissertation.

2.2.3. Cultural Differences Between Iran and Germany

Hofstede (1980) directed a multinational survey analysis to understand the cultural differences among countries. The survey data was collected by questionnaires in 20 different languages from 72 countries. Hofstede (1980) identified patterns in the data, which he named *dimensions*. He defined four dimensions: (1) Power distance: the extent to which the less powerful members of the family or society believe that power is distributed unequally. (2) Uncertainty avoidance: willingness to tolerate ambiguity, which is related to a society's level of comfort with unknown situations (i.e., situations in which unpredictable things may happen). In countries with weaker uncertainty avoidance, not only familiar but also unfamiliar risks will be accepted compare to countries with stronger uncertainty avoidance. (3) Individualism: the extent to which independent contexts are prevalent within a society, and (4) masculinity: the dominant gender roles in the family as well as within a society. This indicates that men in the more masculine countries are more assertive and competitive than in less masculine countries. Each dimension was conceptualized within a single continuum, therefore, members of the societies surveyed could value similar things but to different extents. It also is worth to point out that the survey is for more than 30 years ago and the societies might have changed in this period.

According to Hofstede's survey (1980; Hofstede & Bond, 1988), Iran and Germany differed noticeably in three out of four dimensions (see Figure 2). Iran scored higher in power distance than Germany, which might be associated with the higher economic inequality within Iranian society. Germany, on the other hand, scored higher on individualism, masculinity, and uncertainty avoidance. Individualism is associated with emphasis on the prioritization of the individual over a group, which is prevalent in independence-oriented cultural contexts (e.g., Darwish, & Huber, 2003; Triandis, 1988). Therefore, the higher level of individualism in

Germany implies that an independence-oriented contexts are more prevalent in Germany than in Iran.

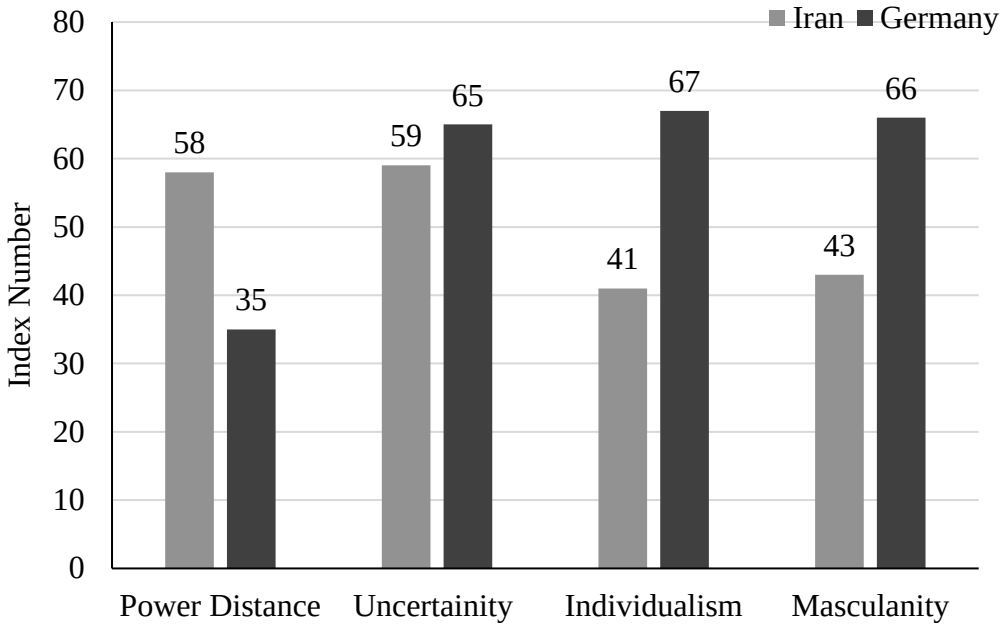

Figure 2. Scores of Iran and Germany on four dimensions of Hofstede's survey (1980). Indices has been brought in a range between 0 and 100.

In the same vein, previous studies have indicated that independence-oriented contexts tend to prevail in Central European and North American countries, whereas interdependence-oriented contexts are dominant characteristics of Asian and Latin American countries (Higgins et al., 2008; Trommsdorff, 2009). In the few available previous cross-cultural/national studies investigating self-regulation, mainly East Asian countries such as Japan and China were compared to Western countries (mostly USA; e.g., Camras et al., 1998; Sabbagh, Carlson, Moses, & Lee, 2006; Trommsdorff & Friedlmeier, 2010). However, Asian countries are very diverse in terms of cultural features, which makes it difficult to generalize their results to all Eastern countries such as the Middle East. For instance, religious beliefs and values as one of the important aspects of cultural context are different between Asian countries: Islam is the largest religion in Middle Eastern countries such as Iran, while most of the East Asian population follows Indian religions (Hackett et al., 2012). This could be particularly important since the relationship between religion and self-regulation have been already shown in the previous research (McCullough & Willoughby, 2009). Middle Eastern countries share a number of

factors, including ethnic groups, geographic features, Islamic religious beliefs, and political history, which provide a different environment than Western or other Asian countries that can influence self-regulation development. However, cross-cultural/national studies on self-regulation are scarce from this region.

Altogether, due to the above-mentioned differences, the present dissertation assumed that Germany and Iran provide two different contexts with distinct cultural characteristics that may affect the self-regulation abilities of children as well as the association between self-regulation and academic performance in young adults. Accordingly, self-regulation ability and its relationship with academic performance were examined in Germany and Iran to contribute to improving the knowledge around self-regulation as a context-sensitive construct.

2.3. Research Aims

As an overarching goal, the present dissertation aims to contribute to the better understanding of the context-sensitivity of self-regulation and its association with academic performance. The development of self-regulation in college students as young adults is deeply embedded in the cultural context in which they grew up, besides they are engaged in education and academic performance. However, although the relation of self-regulation and academic performance is well established for children, studies investigating this relationship in adults are rather scarce, hence requiring further research. Therefore, *Study 1* first investigates the association between different aspects of self-regulation and mathematics performance of college students. *Study 2* then compares the relationship between self-regulation and mathematics performance between German and Iranian college students. Hence, the research questions of *Study 1* and *Study 2* are best considered in conjunction. Moreover, field of study of the college students is taken into account in this dissertation as students from more math-related fields (e.g., Engineering/Informatics) may perform better in a mathematics task than students in less math-related fields (e.g., Human Sciences). The detailed research questions of *Study 1* and *Study 2* are:

I. Do different aspects of self-regulation predict mathematics performance of young adults?
II. Does the relationship between self-regulation and mathematics performance differ between German and Iranian college students?

III. Does the field of study influence the relationship between self-regulation and mathematics performance of college students?

Furthermore, the results of longitudinal studies in Western countries revealed that academic performance can be predicted by a child's self-regulation abilities at preschool age (e.g., Shoda et al., 1990; Watts et al., 2018). Considering different effects of independence- and interdependence-oriented contexts on the development of self-regulation, these results suggest that there might be differences between German and Iranian children at preschool age with respect to self-regulation abilities, which could influence their academic performance in the future. Accordingly, *Study 3* investigates the self-regulation abilities of German and Iranian preschool children before starting the official education. More specifically, self-regulation ability in this study was operationalized as performance and strategies used by children in a delay of gratification paradigm (Mischel, 1996). Moreover, parenting behavior was also considered to examine the relation of parenting behavior and self-regulation abilities of children between the two countries. The research questions of *Study 3* are:

I. Does performance in the delay of gratification task differ between German and Iranian preschool children?
II. Do the self-regulatory behavioral strategies used by children in the delay of gratification task differ between German and Iranian preschool children?
III. Do the self-regulatory behavioral strategies used by German and Iranian preschool children in the delay of gratification task predict their performances?
IV. Does the association between self-regulatory behavioral strategies and the performance of the children in the delay of gratification task differ between German and Iranian preschool children?
V. Do parenting behaviors differ between Germany and Iran?
VI. Do parenting behaviors predict the performance of German and Iranian preschool children in the delay of gratification task?

3. EMPIRICAL STUDIES

3.1. Study 1: Planning and Self-Control, but not Working Memory, Directly Predict Multiplication Performance in Adults[1]

3.1.1. Introduction

People use numerical skills in their everyday life in various situations such as shopping or paying bills at restaurants. About 20% of adults do not achieve basic levels of mathematic competence required for these life skills (Williams, 2003). This mathematic incompetence leads to lower income and less financial security in life (Butterworth, Varma, & Laurillard, 2011; Parsons & Bynner, 2005). Therefore, it is worthwhile to examine the factors that can lead to this incompetency. Two groups of factors that influence mathematical skills have been described in the literature. One group consists of domain-specific factors, such as the approximate number system (e.g., Libertus, Feigenson, & Halberda, 2011; for review see Dietrich, Huber, & Nuerk, 2015) or spatial-numerical associations (e.g., Siegler & Opfer, 2003; but see Cipora et al., 2016). The second group consists of domain-general factors such as social (e.g., Byrnes & Wasik, 2009), behavioral (e.g., McClelland et al., 2007), and cognitive factors (e.g., Bull, Espy, & Wiebe, 2008; Bull & Scerif, 2001).

Various domain-general cognitive abilities have been reported to influence complex arithmetic performance. One category of such abilities is executive functions (EF), which include three core cognitive processes: inhibition, shifting, and working memory (WM; Miyake et al., 2000). There is strong evidence for the contribution of EF to mathematical performance (e.g., Agostino, Johnson, & Pascual-Leone, 2010; Blair & Razza, 2007; Clark, Pritchard, & Woodward, 2010; Cragg & Gilmore, 2014; Gathercole, Pickering, Knight, & Stegmann, 2004; Lee, Ng, & Ng, 2009). The component of EF most frequently associated with complex mathematics is WM, which is a system of storage and manipulation of recent visuospatial and verbal information (Baddeley, 2012; Baddeley & Hitch, 1974). Previous studies have repeatedly

[1] Nemati, P., Schmid, J., Soltanlou, M., Krimly, J. T., Nuerk, H. C., & Gawrilow, C. (2017). Planning and self-control, but not working memory, directly predict multiplication performance in adults. *Journal of Numerical Cognition*, *3*(2), 441-467.

shown that WM is strongly related to different mathematical skills (e.g., Cragg & Gilmore, 2014; De Smedt et al., 2009; Friso-van den Bos, van der Ven, Kroesbergen, & van Luit, 2013; Han, Yang, Lin, & Yen, 2016; Raghubar, Barnes, & Hecht, 2010; Swanson, Jerman, & Zheng, 2008; Szücs, Devine, Soltesz, Nobes, & Gabriel, 2013; Van der Ven, Kroesbergen, Boom, & Leseman, 2012).

WM contributes to basic arithmetic skills (i.e., addition, subtraction, multiplication, division), because these computations require concurrent storage and processing of digits (e.g., Peng, Namkung, Barnes, & Sun, 2016; Raghubar et al., 2010; Swanson & Jerman, 2006). However, WM is differentially related to performance on different types of arithmetic tasks. For example, it has been shown that WM capacity affects both addition and subtraction problem solving through its influence on the ability to retrieve answers from long-term memory (Barrouillet & Lépine, 2005; Barrouillet, Mignon, & Thevenot, 2008; but see Fayol & Thevenot, 2012, for alternative accounts of addition problem solving). However, in multiplication problem solving, it has been suggested that WM is involved in retrieval strategies as well as computation processing (Mabbott & Bisanz, 2003; Seitz & Schumann-Hengsteler, 2000) with an increasing load of WM for complex problems solved via non-retrieval strategies (Tronsky, 2005). Moreover, research indicates that specific domains of WM (e.g., verbal WM and visuospatial WM) may be differentially associated with different types of arithmetic skills (Lee & Kang, 2002). For instance, neuroimaging findings revealed that addition and subtraction problem solving are more associated with visuospatial WM than simple multiplication problem solving, whereas multiplication relies more on retrieval strategies than manipulation of visual Arabic digits (e.g., Zhou et al., 2007). Further studies, however, did not replicate this finding, pointing out limitations and methodological problems with the previous studies (Cavdaroglu & Knops, 2016; Imbo & LeFevre, 2010). As for instance, Cavdaroglu and Knops (2016) suggested that multiplication and subtraction depend on both verbal and visuospatial domains of WM when the difficulty of WM measures and calculation tasks are controlled within and across participants.

Further research suggests that the contribution of different domains of WM to arithmetic skills is influenced not only by the type of problems or domains of WM but also by an individual's age (Menon, 2016). For example, there is some evidence that the contributions of different domains of WM to mathematical performance change dynamically during development, and that visuospatial WM plays an increasing role in improving mathematical

skills (e.g., Menon, 2016; Meyer, Salimpoor, Wu, Geary, & Menon, 2010; Soltanlou, Pixner, & Nuerk, 2015). In sum, different domains of WM seem to affect different arithmetic operations differently at different developmental stages.

However, most of these studies investigated WM as the only domain-general factor predicting arithmetic performance and may, therefore, be misleading because WM is also associated with other EFs such as inhibition and planning (e.g., Hasher, Zacks, & May, 1999; Oberauer, 2001; see also a computational model of frontal lobe dysfunction for relation between WM and planning; Goela, Pullara, & Grafman, 2001). Planning is described as the ability which contributes to problem solving (Newell & Simon, 1972; Simon, 1978). It has been shown that planning is associated with better math problem solving in children (e.g., Clark et al., 2010; Kirby & Ashman, 1984). Poor planning skills are related to failure to organize mathematical problem solving in children, that is, difficulty in analyzing the demands of the problem and using the best procedures to solve it (Naglieri & Johnson, 2000). In addition, improving planning skills has been found to play a beneficial role in interventions for children with poor arithmetic skills (e.g., Naglieri & Johnsonet al., 2000). Hence, it has been suggested that planning is crucial for successful mathematical performance and is linked to cognitive strategies used in mathematical computations (Das, Naglieri, & Kirby, 1994). In spite of the important role of planning in arithmetic computations in the few available studies, studies on the relationship between planning skills and arithmetic computations especially in adults are scarce.

Solving complex multiplication tasks that require different sequences of computations and cognitive processes likely involves planning skills, for instance, organizing the best strategies step by step to solve the problem. Accordingly, we focused on planning ability as well as WM, because it has been suggested that planning is one of the essential skills for mathematical computations (e.g., Kirby & Ashman, 1984; Sikora, Haley, Edwards, & Butler, 2002). Planning also relies on WM (e.g., Albert & Steinberg, 2011; Goela et al., 2001; Köstering, Stahl, Leonhart, Weiller, & Kaller, 2014; Zelazo, Carter, Reznick, & Frye, 1997) to maintain and revise sequences of plans (Gilhooly, 2005) Therefore, we aimed at examining the impact of WM and planning on solving complex multiplication tasks.

In the current study, we used the Tower of London (TOL) task to operationalize planning. The TOL is a common instrument for measuring planning skills in cognitive and clinical studies (Kaller, Rahm, Köstering, & Unterrainer, 2011) and similar to WM it is known to critically rely

on the activity of the prefrontal cortex (for a review see Unterrainer & Owen, 2006). Furthermore, aside from cognitive domain-general factors, few studies have indicated a plausible contribution of behavioral domain-general factors to arithmetic performance (see also Cragg & Gilmore, 2014).

Therefore, in addition to cognitive components, we assessed self-reported self-regulation and self-control as two behavioral factors closely related to cognitive EF factors (Hofmann, Schmeichel, & Baddeley, 2012) that may influence arithmetic performance. Self-regulation can be defined as the ability to control emotions, thoughts, and behaviors (Best & Miller, 2010). An important aspect of self-regulation is goal-directed behavior (Hofmann et al., 2012), as for instance, making an appropriate decision to achieve a previously self-determined goal, by considering different opportunities and acting according to their consequences (McClelland, Geldhof, Cameron, & Wanless, 2015). Self-control as a subset of self-regulation serves more as an active attempt to resist temptations, and is related to overriding unwanted, impulsive responses (Baumeister, 2002; Diamond, 2013). For instance, self-control may be required to resist eating a high-calorie desert while on a diet or to suppress unwanted, distracting thoughts while solving math problems. Another aspect of self-control is to have the discipline to not give up a task despite tempting action opportunities (Diamond, 2013; Duckworth, Peterson, Matthews, & Kelly, 2007). This perseverance is important because achieving difficult long-term goals, such a future educational success, requires maintaining effort and interest over time (Duckworth et al., 2007). Completing a difficult time-consuming task such as a complex math task may also depend on discipline and perseverance to some extent.

Previous studies have indicated that both self-regulation and self-control can predict mathematical performance in children (e.g., Blair & Razza, 2007; Gawrilow, Gollwitzer, & Oettingen, 2011). However, studies on the relationship between self-regulation, self-control, and arithmetic performance are rather scarce. The few existing studies indicate that self-regulation and self-control may contribute to mathematical performance by blocking out distracting information (e.g., Gawrilow et al., 2011; Passolunghi & Siegel, 2001) and through their relations to various components of EF such as inhibition or WM (e.g., Best & Miller, 2010; Hofmann, Friese, Schmeichel, & Baddeley, 2011; McClelland & Cameron, 2012; McClelland et al., 2007). Previous studies have also shown that WM is related to self-regulation and self-control (Hofmann et al., 2011). For instance, self-regulation involves WM in representing goals and

updating goal-related information (Kane, Bleckley, Conway, & Engle, 2001; Miller & Cohen, 2001). In support of the influence of WM on self-control, previous research has shown that individuals with higher WM capacity are more able to resist visual distractors in various visual tasks than individuals with less WM capacity (e.g., Kane et al., 2001; Unsworth, Schrock, & Engle, 2004). Therefore, an assumption underlying the use of these behavioral ratings (i.e., self-regulation and self-control) is that they are measuring behaviors that are related to both arithmetic performance and WM. Accordingly, we aimed to test whether WM explains unique variance when these WM-related behavioral components (i.e., self-regulation and self-control) are considered.

In the present study, we assessed complex multiplication because it requires a variety of cognitive skills (Han et al., 2016). For instance, WM is necessary for maintaining and updating information and step-by-step planning, and self-regulation and self-control are needed for ignoring distractions such as intrusive thoughts. In addition, previous studies that examined domain-general factors contributing to simple multiplication performance identified WM as the most relevant cognitive process (e.g., Han et al., 2016; Soltanlou et al., 2015), but little is known about the role of other domain-general cognitive demands in complex multiplication problem solving. Therefore, we aimed to investigate whether any of these domain-general factors can predict complex multiplication performance better than WM.

Furthermore, we investigated the operand-relatedness effect, which has been mostly implicated in simple multiplication. Operand-relatedness within multiplication refers to the solution belonging to another problem, mainly the neighbors of the correct solution in the multiplication table (e.g., $3 \times 7 = 24$). Studies have shown that this effect leads to slower response times and more errors in simple multiplication (e.g., Campbell & Graham, 1985; Cooney, Swanson, & Ladd, 1988; Stazyk, Ashcraft, & Hamann, 1982). Theoretical models of multiplication processing such as network retrieval (Ashcraft, 1982), distribution of association (Siegler, 1988), and network interference (Campbell, 1987) interpreted this effect within the framework of a network of nodes comprising the solutions of problems belonging to the multiplication table, which are related to each other. Therefore, we aimed to extend the operand-relatedness effect that previously has been shown in simple multiplication to complex multiplication in the current study.

In sum, in the present study, we investigated the relation of the aforementioned domain-general factors to complex multiplication problem solving to determine which one is the best predictor of complex multiplication performance in adults, and to test whether any of these domain-general factors can predict complex multiplication performance better than WM. Regarding the operand-relatedness effect, we hypothesized that although we usually do not learn complex multiplication from a table, due to step-by-step computations (i.e., first multiplying unit to unit, following to multiplication table, then unit to decade), the operand-relatedness effect may exist in complex multiplication.

To examine our hypotheses, we employed computerized tasks to measure cognitive factors (i.e., WM and planning) and online questionnaires to assess behavioral factors (i.e., self-regulation and self-control). Furthermore, participants performed computerized complex multiplication task in our laboratory.

3.1.2. Methods

Participants

Forty undergraduate students (33 females, age: M = 20.95 years, SD = 1.08) of a small German University participated in this study. All participants received detailed information about the study and then gave written informed consent to participate in the study. They received either course credits or eight Euro per hour. Detailed sample characteristics are provided in Appendix A. All data were collected pseudonymised (i.e., not labeled by name) using personal codes.

Measures

Working Memory (WM)

To assess WM, we used visuospatial WM tasks (i.e., N-Back and Corsi block-tapping) because they have been shown to have strong relations with multiplication performance (e.g., Han et al., 2016; Soltanlou et al., 2015).

N-Back: The N-Back task had a spatial 2-Back design, where in each trial one of the following capital letters: B, F, K, H, M, Q, R, X, (Kane, Conway, Miura, & Colflesh, 2007) plus L and S was presented in the left or right field of a two-split grid frame on the screen. Participants were instructed to press a green button (i.e., L on a German keyboard) if the presented letter and its position in the two-grid frame matched the one presented two trials before

(2-Back), and to press the red button (i.e., A on a German keyboard) if it did not match. The response keys were counterbalanced across participants. Each two-split grid with a letter was presented for 1000 ms and then disappeared from the screen. Response duration was 3000 ms from the time that two-split grid was presented. The inter-stimulus interval was 1000 ms. The task began with 10 practice trials, followed by 320 test trials. The target condition (the condition in which the presented letter and its position match the condition presented two trials before) constituted 30% of all trials.

Corsi Block-Tapping: The computerized version of the Corsi block-tapping task was used (Corsi, 1973), chosen from the Psychology Experiment Building Language test battery (PEBL; Mueller, 2013). The test consisted of nine black 1/4-inch cubes distributed over a gray screen. On any given trial, some of the cubes lit up in a particular sequence, starting with three lighted-cubes sequence. There were two trials for each sequence. The sequence was increased by one when at least one of two trials of the same sequence was recalled correctly. Otherwise, the test was stopped and the maximum length of sequences with at least one correct recall was calculated as the score. In the forward recall, participants were asked to use the cursor to tap the cubes in the same order as they had lit, while in the backward recall, the procedure was the same in reversed order. A maximum of 18 test trials was presented.

Planning

Tower of London (TOL): The computerized version (Kaller et al., 2011) of the TOL task (Shallice, 1982) was used in the present study to assess planning. Participants were instructed to solve a set of TOL problems (Kaller et al., 2011) which consisted of 28 trials of three-, four-, five-, and six-move problems (eight trials each except four trials for the three-move problem) presented in fixed order. The test contained two boards (reference and test). Each board had three pegs and three balls with three different colors: blue, yellow and red. Participants were asked to move the balls on the test board in order to make the arrangement of the balls identical to the patterns on the reference board shown on top of the screen. Participants were instructed to plan how to move the balls before starting to move them and to use the minimum number of moves to solve the problems. The accuracy score was calculated as the number of problems solved correctly in the minimum number of moves within the time limit divided by the total number of problems.

Complex Multiplication

In total, 48 complex multiplication problems (Appendix B) along with their solutions were presented in a computerized verification task. The computerized complex multiplication task was created with PsychoPy software (Peirce, 2009). The multiplication problems consisted of a one-digit operand (range: 2-9) times a two-digit operand (range: 13-19), with two-digit solutions (range: 48-98). Presented solutions consisted of correct (50%) and incorrect (50%) solutions. Half of the incorrect solutions were operand-related solutions and the other half were operand-unrelated solutions. Operand-related solutions differed from the correct solution by ±1 to one of the operands. Therefore, they were neighbors of the correct solution in the multiplication table. Operand-unrelated solutions were not from the multiplication table. The operand-related solutions were matched by distance difference to the correct solutions and parity with operand-unrelated solutions. The experiment started with 8 practice trials. Multiplication problems along with solutions were presented at the same time in the center of the screen in the form of x × xx = xx in half of the trials, and in the form of xx × x = xx in the other half. The order of small and large operand within the trials was counterbalanced. Trials were presented to participants in a fixed order. Each trial started with a fixation point of 500 ms, followed by a blank screen for 500 ms. Then a multiplication problem along with a solution (e.g., 4 x 19 = 76) was presented until a response was made or a limited time of 6000 ms passed. Participants were asked to respond by pressing a green key (L in German keyboard) when the solution was correct and a red key (A in German keyboard) when the solution was incorrect. The response keys were counterbalanced across participants. After response or no response in given time (6000 ms), the presented problem disappeared and 1000 ms later next trial began. No feedback was provided.

Self-Regulation and Self-Control

German short versions of the Brief Self-control Scale (sample item: “I wish I had more self-discipline”; Bertrams & Dickhäuser, 2009; Tangney, Baumeister, & Boone, 2004), and of the Conners’ adult attention-deficit/ hyperactivity disorder (ADHD) Rating Scale (sample item: “I am easily bored”; CAARS; Conners, Erhardt, & Sparrow, 1999) were used to assess self-regulation and self-control, respectively. We used ADHD rating scales for measuring self-regulation, because a deficit in self-regulation is one of the major behavioral problems in ADHD (Barkley, 1997). In addition, attention plays a significant role in self-regulation (e.g., Norman

and Shallice's Supervisory Attention System; Norman & Shallice, 1986). The online questionnaire was created with SoSci Survey (Leiner, 2014) for both of our behavioral ratings (i.e., Brief Self-control Scale and CAARS).

Procedure

This study was part of a larger project, which aimed to investigate the effect of self-regulatory training on mathematical performance. First, an online questionnaire consisting of items for assessing demographic information, self-regulation, and self-control, was sent via email to each participant. After responding to the online questionnaire, participants were invited to our laboratory to perform computerized tasks in individual sessions. Subsequently, WM, planning, and multiplication performance were assessed using computerized tasks in the lab. Each task lasted approximately 10-15 min. Half of the participants completed the domain-general cognitive tasks first, and the other half completed the multiplication task first. Written detailed instructions emphasizing both speed and accuracy were presented before each task.

Analysis

Response times (RTs) of participants in complex multiplication task were measured by key-press, and defined by the time interval between the presentation of the problems and the response. Only RTs for correct responses were included in the analyses. Furthermore, RTs shorter than 200 ms were not considered. In a second step, RTs outside of the interval of ±3 SD around the individual mean were excluded repetitively until no more outliers remained (for the same procedure see Nuerk, Weger, & Willmes, 2001, and follow-up articles). Therefore, about 0.11% of the responses were not considered for further analyses. Moreover, four trials (with the same components but different correct and incorrect solutions) were excluded because they were presented with wrong solutions in the task.

In order to find the relation between domain-general factors and multiplication performance, a bivariate correlation was calculated. Moreover, to uncover which domain-general factors predict multiplication performance in adults, two separated stepwise regression analyses were conducted on mean RTs and error rates. It should be noted that prior to regression analysis, the WM variables were aggregated by adding z-scores of Corsi block-tapping task and z-scores of N-back task accuracy to guarantee adequate statistical power of the model by reducing the number of predictors. The same procedure was conducted with WM non-aggregated measures to

provide full insight into the non-aggregated WM measures. Furthermore, there was a statistically significant correlation between WM tasks (see Table 1), as they all assessed visuospatial WM. Full information on separate contributions of the single WM tasks to multiplication performance can be found in Table 3. Due to the strong correlation between TOL task and WM measures, an additional mediation analysis was conducted to test whether the variance explained by WM in multiplication errors was included in the TOL task. Finally, the operand-relatedness effect was calculated by using paired t-test between operand-related and operand-unrelated conditions.

3.1.3. Results

Relation between Multiplication Performance and Domain-General Factors

Descriptive Statistics and Correlation Analysis: Descriptive statistics for all study variables are provided in Table 1 along with the correlation matrix. Furthermore, the analysis of ceiling and floor effect for all variables revealed a ceiling effect in the N-Back task (Appendix C). Multiplication error rate was significantly negatively correlated with planning accuracy (r = -.43, p = .003), and there was a significant negative correlation between multiplication RT and self-control (r = -.34, p = .015; see Table 1). Moreover, several significant correlations were observed within domain-general factors. Planning accuracy showed a significant correlation with self-control (r = -.45, p = .002) and WM aggregated measures (r = .50, p = .001). There was a significant correlation between self-regulation and N-Back accuracy (r = .28, p = .042). Moreover, significant correlations were found between three WM tasks and between planning accuracy and WM tasks (Table 1).

Table 1.

Descriptive Statistics and Correlations between Domain-General Factors and Multiplication Performance

Variable	*M* (*SD*)	1	2	3	4	5	6	7	8
1. Multiplication Error (%)	0.18 (0.11)	-							
2. Multiplication RT (ms)	3.10 (0.56)	.27*	-						
3. Self-Regulation	13.62 (5.57)	-.17	-.00	-					
4. Self-Control	41.42 (8.74)	.04	-.34*	-.17	-				
5. N-Back Accuracy	0 .87 (0.09)	-.30*	-.16	.28*	.04	-			
6. Corsi-Block Forward	5.50 (0.65)	-.27*	-.05	.22	-.18	.35*	-		
7. Corsi-Block Backward	6.05 (0.81)	-.18	.15	.22	-.20	.31*	.47**	-	
8. TOL Accuracy	0.73 (0.13)	-.43**	.13	.23	-.45**	.53**	.36*	.25	-
9. WM[a]	0.00 (5.27)	-.33*	-.03	.31	-.15				.50**

Note. N = 40. [a]WM = aggregated WM tasks including Corsi Block-Tapping Forward, Corsi Block-Tapping Backward, and N-Back Accuracy. Ranged between -5.65 and 5.11. *p < .05. **p < .01, one-tailed.

Regression Analysis: Stepwise multiple regression analysis was conducted to test whether self-regulation, self-control, WM, and TOL accuracy significantly predict participants' performance in the multiplication task. Two series of stepwise regression analyses were separately conducted for multiplication error rate and RT as dependent variables. The stepwise model of total error rate, R^2 = 0.18, adjusted R^2 = 0.16, F(1, 38) = 8.59, p = .006, showed only TOL accuracy as a significant predictor (p = .006), while the other predictors failed to explain significant amounts of additional variance (Table 2). The stepwise model of total RT, R^2 = 0.12, adjusted R^2 = 0.09, F(1, 38) = 5.11, p = .029, identified only self-control ratings as a significant predictor (p = .029), while the other predictors failed to explain significant amounts of additional variance (Table 2). Furthermore, the results of multiple regression analyses with non-aggregated

WM tasks as predictors were largely consistent with aggregated WM tasks and are presented in Table 3.

Table 2.

Stepwise Multiple Regression Analysis Predicting Complex Multiplication Performance from TOL Accuracy, Self-Regulation, Self-Control, and WM

Dependent variable	Predictor	Excluded variable	*B*	*t*	*p*	Standardized *B*
Total errors (%)	TOL Accuracy		-0.35	-2.93	.01*	-0.43
		Self-Regulation	-0.08	-0.52	.60	
		Self-Control	-0.19	-1.15	.26	
		WM[a]	-0.15	-0.90	.37	
RT (ms)	Self-Control		-0.02	-2.26	.03*	-0.34
		Self-Regulation	-0.06	-0.41	.69	
		WM	-0.08	-0.52	.61	
		TOL Accuracy	-0.03	-0.20	.84	

Note. $N = 40$. [a]WM = aggregated WM tasks including Corsi block-tapping forward, Corsi block-tapping backward and N-Back accuracy. *$p < .05$.

Table 3.

Stepwise Multiple Regression Analysis Predicting Complex Multiplication Performance From TOL Accuracy, Self-Regulation, Self-Control, and Non-Aggregated WM Tasks

Dependent variable	Predictor	Excluded variable	*B*	*t*	*p*	Standardized *B*
Total errors (%)	TOL Accuracy		-0.35	-2.93	.01*	-0.43
		Self-Regulation	-0.08	-0.52	.60	
		Self-Control	-0.19	-1.15	.26	
		Corsi Block Forward	-0.13	-0.83	.41	
		Corsi Block Backward	-0.08	-0.52	.60	
		N-Back Accuracy	-0.10	-0.60	.55	
RT (ms)	Self-Control		-0.02	-2.26	.03*	-0.34
		Self-Regulation	-0.06	-0.41	.69	
		Corsi Block Forward	-0.11	-0.73	.47	
		Corsi Block Backward	-0.08	0.51	.61	
		N-Back Accuracy	-0.15	-0.96	.34	
		TOL Accuracy	-0.03	-0.20	.84	

Note. $N = 40$. *$p < .05$.

Mediation Analysis: Mediation analyses were conducted following the guidelines by Baron and Kenny (1986) to test whether planning accuracy (measured by TOL) is a mediator in the relationship between WM and multiplication performance. Thus, TOL accuracy might predict multiplication errors, and WM may predict multiplication errors indirectly through TOL accuracy because WM measures and TOL accuracy were strongly correlated (Table 1). If WM predicts TOL accuracy, which in turn predicts multiplication errors, regression analyses may not be the appropriate model to use. The direct influence of WM on multiplication errors would not explain variance, because this variance would already be accounted for by the planning variable (influenced itself by WM). We tested this assumption with both the aggregated (Figure 1) and the non-aggregated WM measures (Figure 2). The effect of aggregated WM on multiplication

errors without controlling for TOL accuracy was significantly negative, (b = -0.02, p = .039; Path *c*, see Figure 1 and Appendix D). However, when TOL accuracy was entered into the model the direct effect of WM on multiplication errors was reduced and no longer significant (b = -0.01, p = .357; Path *c´*, see Figure 1). Instead, WM influenced TOL accuracy significantly (b = 0.03, p = .001; Path a, see Figure 1), which in turn influenced multiplication errors significantly (b = -0.29, p = .032; Path *b*, see Figure 1 and Appendix D). The one-tailed Sobel test confirmed that there is a significant indirect effect of WM on multiplication error through TOL accuracy (b = -0.01, p = .030). Therefore, the mediation model supported the assumption that TOL accuracy mediates the effect of aggregated WM measures on multiplication errors (Figure 1).

Figure 1.

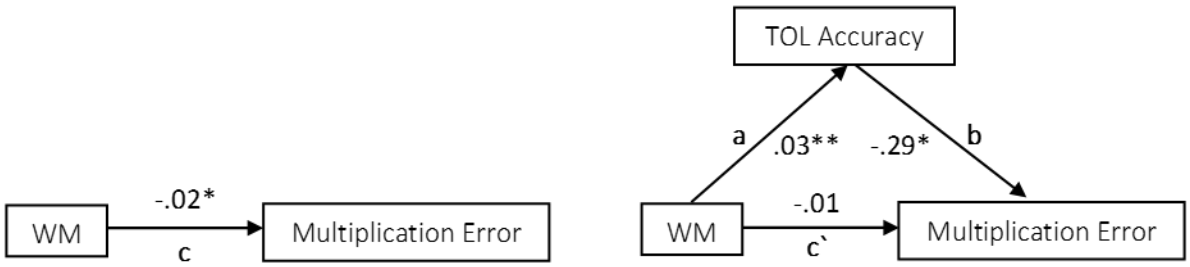

Figure 1. Mediation model being tested on the basis of Baron and Kenny (1986). Path *c* tested the relationship (left diagram) between the independent variable and the dependent variable without controlling for TOL Accuracy, path *a* tested the relationship (right diagram) between the mediator and the independent variable and path *c´* tested the direct relationship between the independent variable and the dependent variable when controlling for TOL Accuracy. Multiplication Error = dependent variable, WM = independent variable (aggregated WM measures), TOL Accuracy = mediator (planning accuracy).

*p < .05. **p < .01.

Figure 2.

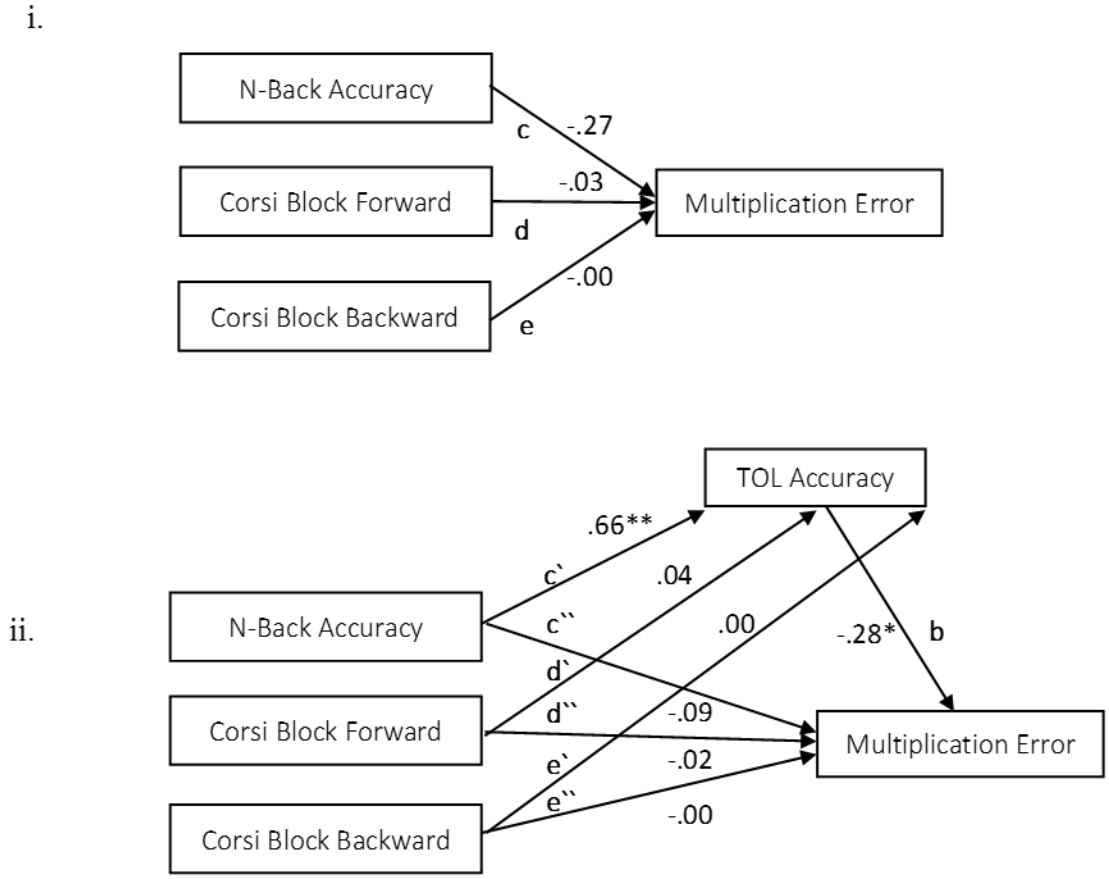

Figure 2. Path analysis model tested the mediator role of TOL accuracy in the direct (i) and indirect (ii) relationships between the independent variables (non-aggregated WM measures) and the dependent variable (multiplication errors). Multiplication Error = dependent variable; N-Back = independent variable; Corsi-Block Forward = independent variable; Corsi-Block Backward = independent variable; TOL Accuracy = mediator (planning accuracy). *$p < .05$. **$p < .01$.

The effects of non-aggregated WM measures on multiplication errors without controlling for TOL accuracy were not significant (Path *c*, *d*, *e*; see Figure 2 and Appendix D). When TOL accuracy was entered into the model, the already insignificant direct effects of non-aggregated WM measures on multiplication errors were further reduced (Path *c´´*, *d´´*, *e´´;* see Figure 2). However, TOL accuracy influenced multiplication errors significantly ($b = -0.28$, $p = .032$; Path

b, see Figure 2 and Appendix D). The effects of Corsi-Block forward (*b* = -0.02, Path *d´´*) and Corsi-Block backward (*b* = -0.00, Path *e´´*) on multiplication error with controlling for TOL accuracy were not significant. However, the results of a one-tailed Sobel test confirmed a significant indirect effect of N-Back accuracy on multiplication error through TOL accuracy (*b* = -0.18, *p* = .041). In sum, the mediation analysis with non-aggregated WM measures suggests that TOL accuracy partially mediates the effect of non-aggregated WM measures on multiplication errors (Figure 2) and N-Back accuracy explains most variance in the indirect path between WM measures and multiplication errors.

Furthermore, additional mediation analyses were conducted to test the extent to which the relationship between TOL accuracy and multiplication error is mediated by WM measures and explore the common and specific multiplication accuracy variance predicted by TOL and WM measures (Appendix E). The results showed that WM (both aggregated and non-aggregated) partially mediated the effect of TOL accuracy on multiplication errors (Appendix E). However, the results of the Sobel test indicated a non-significant indirect effect of TOL accuracy on multiplication error through aggregated WM measures (*b* = -0.06, *p* = .401) and non-aggregated WM measures (N-Back Accuracy, *b* = -.03, *p* = .695; Corsi-Block Forward, *b* = -0.03, *p* = .590; Corsi-Block Backward, *b* = -0.00, *p* = .918).

Comparison of Operand-Related and Operand-Unrelated

The operand-relatedness effect in multiplication was replicated in this study by using paired *t*-tests between operand-related and operand-unrelated conditions. Participants made significantly fewer errors in the operand-unrelated condition (*M* = .12; *SD* = .12) than the operand-related condition (*M* = .20; *SD* = .10), *t*(39) = 3.96, *p* < .001. Furthermore, participants were significantly faster in the operand-unrelated condition (*M* = 2.88; *SD* = .64) than the operand-related condition (*M* = 3.14; *SD* = .60), *t*(39) = 4.25, *p* < .001. However, no domain-general cognitive factor significantly predicted variance for the operand-relatedness effect.

3.1.4. Discussion

The present study investigated the role of domain-general factors including WM, planning, self-regulation, and self-control abilities in complex multiplication performance in adults. Consistent with previous studies in children (e.g., Bull et al., 2008; Bull & Lee, 2014;

Clark et al., 2010; Von Aster & Shalev, 2007), our overall findings indicate that domain-general factors support mathematical performance in adults.

The Role of WM and Planning as Cognitive Factors in Multiplication Performance

Although most previous studies emphasized the major role of WM in multiplication performance (e.g., Soltanlou et al., 2015), interestingly we found a dominant influence of domain-general planning on complex multiplication problem-solving in adults. Moreover, the results of regression analysis with non-aggregated WM measures were largely consistent with aggregated WM measures. Therefore, WM in both aggregated and non-aggregated analyses failed to directly account for complex multiplication performance, probably because WM exerted its influence indirectly via TOL performance, as TOL is strongly associated with the WM measures (Table 1). Indeed, the results of mediation analyses showed that this was the case (Figure 1). Both the aggregated WM measures (Figure 1) as well as the N-Back measure in the non-aggregated analysis (Figure 2) predicted planning performance, which in turn predicted multiplication performance. The non-significant effect of WM on multiplication performance can thus not be interpreted such that WM is not important for multiplication performance. Instead, it seems that WM continues to influence multiplication performance, but indirectly as part of planning. However, in a longitudinal study by Bull and colleagues (2008) on arithmetic performance in pre-school and primary school children, WM measures predicted the variance in arithmetic performance despite the effect of the TOL task. The finding of our study is partially in line with this longitudinal study, which reported a predictive role of planning, memory, and inhibition in mathematical problem solving (Bull et al., 2008). The authors reported visuospatial short-term memory and verbal WM as the best predictors, and then planning as a better predictor than inhibition. Therefore, in accordance with our study, planning predicts arithmetic variance, but in contrast to our results, WM also predicts unique variance in Bull and colleagues (2008). One reason might be the effect of age; we tested adults, while Bull and colleagues (2008) tested children. Age effects on cognitive components predicting multiplication performance have already been shown in previous studies, even with small age changes such as one school year (e.g., Soltanlou et al., 2015). Therefore, the predictors of arithmetic performance in children and adults may differ.

The other reason for the differences between the study by Bull and colleagues (2008) and our study might be the type of problems. Bull and colleagues (2008) used simple math tasks for

pre-school children, but we used complex multiplication task in the current study to measure complex arithmetic computations. Multi-digit multiplication requires sequential planning and processing (mostly unit × unit, then unit × decade, and then in the case of carrying, adding the decade of first calculation to the second). This complexity might result in stronger associations with complex tasks - in this case, complex multiplication - that require different cognitive processes simultaneously. Therefore, this study shows that planning, as a more complex cognitive factor, is a better predictor of complex arithmetic performances in adults. This account is also consistent with the theoretical idea that planning has a multi-componential nature in adults including different skills, particularly visuospatial WM (e.g., Albert & Steinberg, 2011; Köstering et al., 2014). It is also in line with a recent study by Han and colleagues (2016), which found that even within updating WM tasks, the more complex task was a better predictor of complex multiplication performance in adults. In sum, on the basis of this new literature, the important influence of planning on complex multiplication and the disappearance of unique WM variance when planning is considered can be reconciled with the more recent studies and theories on the topic.

Finally, there might be a methodological reason for the differences between the study by Bull and colleagues (2008) and our study. Although the N-Back task was the only significant predictor in our mediation analysis, the performance of our participants indicated a ceiling effect, as they made few errors (Appendix C). It is conceivable that when a more difficult version of the N-Back task is used in future studies, there may be more variance, leading not only to an indirect contribution of WM via planning, but also to a direct contribution.

In summary, on the basis of the current data, we can be confident that planning plays a major role in predicting complex multiplication performance, and that WM exerts influence on complex multiplication performance indirectly via planning. However, what requires further investigation is whether WM explains the unique variance of complex multiplication performance in addition to the indirect influences exerted via planning. In our data, this is not the case, but it remains possible for other WM tasks.

The Role of Self-Regulation and Self-Control as Behavioral Factors in Multiplication Performance

Regarding multiplication RT, self-control was the only significant predictor: more self-control was associated with faster responses. One reason could be that procedural arithmetic

computations (i.e., step-by-step computation during arithmetic problem solving) require concentrating and ignoring irrelevant information, which in turn rely on self-control (e.g., Gawrilow et al., 2011; Passolunghi & Siegel, 2001). Therefore, participants with more self-control were better able to suppress unwanted thoughts and to ignore distracting information, which is associated with faster computations and more rapid responses. This finding is in line with previous studies suggesting an association between self-control ability and better performance in various tasks (e.g., Gawrilow et al., 2011; Passolunghi & Siegel, 2001). Furthermore, it is consistent with previous studies suggesting that people with self-control deficits, such as patients with frontal lobe dysfunctions, exhibit slower RTs with high variability across wide range of tasks (e.g., Dimoska, Johnstone, Barry, & Clarke, 2003; Kofler et al., 2013; Senderecka, Grabowska, Szewczyk, Gerc, & Chmylak, 2012).

However, unexpectedly, self-regulation did not show any relation to complex multiplication performance in the present study. One possible reason could be the insufficiency of our measurement instrument (i.e., ADHD symptoms self-report) that was used for assessing self-regulation in healthy adults in this study. Although a strong association between ADHD symptoms and self-regulation deficits exists in individuals with ADHD (Barkley, 1997; Nigg, 2006), this association might not be as valid in healthy adults with limited variance in self-regulation.

Operand-Related and Operand-Unrelated

Interestingly, in the present study, the operand-relatedness effect was found in complex multiplication, which suggests an extension of this effect beyond the multiplication table. Although several studies in adults (e.g. Campbell, 1997; Domahs, Delazer, & Nuerk, 2006) and children (e.g., Butterworth, Marchesini, & Girelli, 2003; Koshmider & Ashcraft, 1991; Lemaire & Siegler, 1995) reported operand-relatedness effect in one-digit multiplication problems, the current study is – to the best of our knowledge – the first study that reports this effect in two-digit multiplication. In accordance with our hypothesis, because of step-by-step computations, we found that the operand-relatedness effect exists even in complex multiplication, which mostly stems from multiplying units.

Limitations of the Current Study

An important limitation of the current study is that participants were all university students and not representative of the general population. An additional limitation was the lack of latent variable approach regarding EFs as we did not assess different indicators for EF core components (i.e., inhibition, shifting, updating WM; Miyake et al., 2000) that contributed differentially to performance in the complex EF tasks. Future studies should have a similar componential approach and explore differential roles of EF components in all basic arithmetic operations in other populations and age groups as well. That might contribute to better understanding of multiplication incompetency in people with arithmetic problems.

Furthermore, in the current study, we used a visuospatial N-Back task which included letters as stimuli in the two-split grid frames. Participants were asked to remember the letters as well as their location to answer correctly. Hence, performance in our N-Back task might also recruit verbal WM capacity to some extent. It could not predict complex multiplication performance when other domain-general factors such as planning and self-control were considered. However, verbal and visuospatial WM were not disentangled in our study, which is a limitation, because some previous studies suggest a stronger involvement for verbal WM than visuospatial WM in multiplication performance (e.g., Dehaene & Cohen, 1997; Lee & Kang, 2002). Moreover, other studies indicated that both verbal and visuospatial domains of WM have an important role in multiplication performance when the difficulty of the tasks are balanced within and between participants (e.g., Cavdaroglu & Knops, 2016). Therefore, our suggestion for future studies is to control the difficulty of the tasks within and between participants as well as to properly disentangle the predictive role of verbal WM and visuospatial WM with a latent variable approach: both verbal and visuospatial WM tasks should be considered in one single study to clarify their possible incremental (direct) contributions to complex multiplication performance in adults, in addition to planning and the N-Back task. Our data suggest that visuospatial WM may not predict unique variance in addition to planning; however, that does not preclude that other domains of WM may do so.

In addition, consistent with previous research indicating that people with self-regulation deficits such as people with ADHD may have difficulties in visuospatial WM (e.g., Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Rommelse et al., 2008; Westerberg, Hirvikoski, Forssberg, & Klingberg, 2004), our data showed an association between less severe ADHD symptoms and better performance in the N-Back task in healthy adults. However, it has been

shown by the other studies that ADHD patients comorbid with dyslexia seem to have deficits in verbal WM (e.g., Bental & Tirosh, 2007; Willcutt et al., 2001) Therefore, our suggestion for the future studies is to include verbal WM as well as visuospatial WM in the same study in ADHD patients with and without different comorbidities to elucidate their contributions to complex multiplication performance as well as to test whether self-regulation deficits can affect multiplication performance through verbal WM or visuospatial WM difficulties.

Another point is that since both complex multiplication and planning were the most complex tasks, a stronger correlation between the two is not surprising. This assumption needs to be tested in future studies that investigate the correlation between simple arithmetic and planning or consider additional complex tasks to examine the uniqueness of the relationship between planning and complex multiplication. Finally, as outlined above, there was a ceiling effect in our N-Back task (Appendix C). Participants made few mistakes in this task. Nevertheless, the N-Back task was the strongest predictor of planning in the mediation model (Figure 2). With a more difficult version of the task and more variance between participants, the influence on planning could be even more pronounced, and a direct influence on multiplication might be revealed, in addition to the indirect influence already shown here.

3.1.5. Summary and Conclusions

The findings of the present study show that planning is a better predictor for multiplication accuracy than other domain-general factors (i.e., WM, self-control, and self-regulation). This might be traced back to procedural processes that are required for both planning and complex multiplication problem solving, and may also be due to the multi-componential nature of planning which involves other domain-general factors such as WM. For both dependent variables, the hallmark construct of domain-general factors, WM, no longer explained any unique variance when other cognitive and behavioral domain-general factors were considered. However, due to the strong association between WM and planning and the results of mediation analyses, we cannot conclude that WM has no influence on multiplication performance, but rather that it influences complex multiplication performance through planning performance. The mediation analyses seem to suggest that WM is part of the planning component of EF, which may be most relevant for more complex arithmetic computations. We conclude that more domain-general factors engaged in arithmetic processing need to be taken into account when the total influence of one factor like WM is examined. However, as we argued in our limitation

section, our findings are restricted to well-educated adults, namely university students, and to complex multi-digit multiplications as well as particular assessment tasks and the complexity of the version used. Whether these results generalize to other age groups, less skilled individuals, and less complex problems and other ways to assess WM and planning as well as other control measures remains an important question for follow-up studies. Nevertheless, we argue that our results strongly suggest that not only WM, but other domain-general factors need to be considered to better understand the foundations of arithmetic performance.

Appendix A

Sample Background Characteristic

Variables[a]	Entire Sample (*N* = 40)
M Age in years (*SD*)	20.95 (1.08)
Gender	
Female	33
Handedness	
Right	39
Field of study	
Psychology, %	40
Cognitive Science, %	37
Medicine, %	8
Media, %	2
Educational	8
Science, %	
Environment	5
Science, %	
Participation payment	
Course credit	16
Money	24
Math score in University entrance exam	
below 8	7
8 to 11	12
12 to 15	21

[a]Information obtained from background online questionnaire.

Appendix B

Complex Multiplication Stimuli

First operand	Second operand	Correct Solutions	Incorrect Solutions	
			Operand-related[a] Errors	Operand-unrelated Errors
4	19	76	72	90
13	7	91	84	86
14	6	84	98	80
17	5	85	90	82
18	3	54	57	59
3	19	57	76	64
5	13	65	70	68
16	3	48	51	34
7	14	98	84	79
15	6	90	75	94
18	4	72	68	91
5	19	95	90	88

[a]operand-related errors are matched by Mean, Mean distance difference from correct solutions and parity to operand-unrelated errors.

Appendix C

Ceiling/Floor Effect in Cognitive and Behavioral Measures

Variable	*M (SD)*	*K-S*[a]	*Skewness*	*Kurtosis*
Multiplication Error (%)	0.18 (0.11)	.03	1.02	1.18
Multiplication RT (ms)	3.10 (0.56)	.20	0.27	0.19
Self-Regulation	13.62 (5.57)	.13	0.82	1.15
Self-Control	41.42 (8.74)	.20	0.18	-0.36
N-Back Accuracy	0 .87 (0.09)	.01	-1.79	3.98
Corsi Forward	5.50 (0.65)	.13	0.22	-0.68
Corsi Backward	6.05 (0.81)	.00	0.95	1.39
Planning Accuracy	0.73 (0.13)	.00	-0.80	0.02

Note. $N = 40$. [a]Kolmogorov-Smirnov p-values.

Appendix D

Table D.2.

Path Model Statistics for TOL Accuracy as Mediator of Aggregated WM Measures and Multiplication Errors (%)

	Dependent Variable: Multiplication Errors (%)				
Variable	Path Identifier	*B*	Standardized *B*	*SE*	*p*
TOL[a] Accuracy	b	-.29	-.35	.13	.03
WM[b]	a	.03	.50	.01	.00
	c	-.01	-.33	.01	.04
	c´	-.01	-.15	.01	.36

Note. $N = 40$. [a]TOL = Tower of London. [b]Aggregated WM measures.

Table D.2.

Path Model Statistics for TOL Accuracy as Mediator of Non-Aggregated WM Measures and Multiplication Errors (%)

Variable	Dependent Variable: Multiplication Errors (%)				
	Path Identifier	*B*	Standardized *B*	*SE*	*p*
TOL[a] Accuracy	b	-.28	-.35	.14	.05
N-Back Accuracy	c	-.27	-.24	.17	.12
	c´	.66	.48	.19	.00
	c´´	-.09	-.08	.20	.66
Corsi-Block Forward	d	-.03	-.18	.03	.24
	d´	.04	.20	.03	.14
	d´´	-.02	-.11	.03	.54
Corsi-Block Backward	e	-.00	-.03	.02	.87
	e´	.00	.01	.02	.93
	e´´	-.00	-.02	.02	.90

Note. $N = 40$. [a]TOL = Tower of London

Appendix E

Path Model Statistics for Aggregated and Non-Aggregated WM Measures as Mediator of TOL Accuracy and Multiplication Errors (%)

Figure E1.

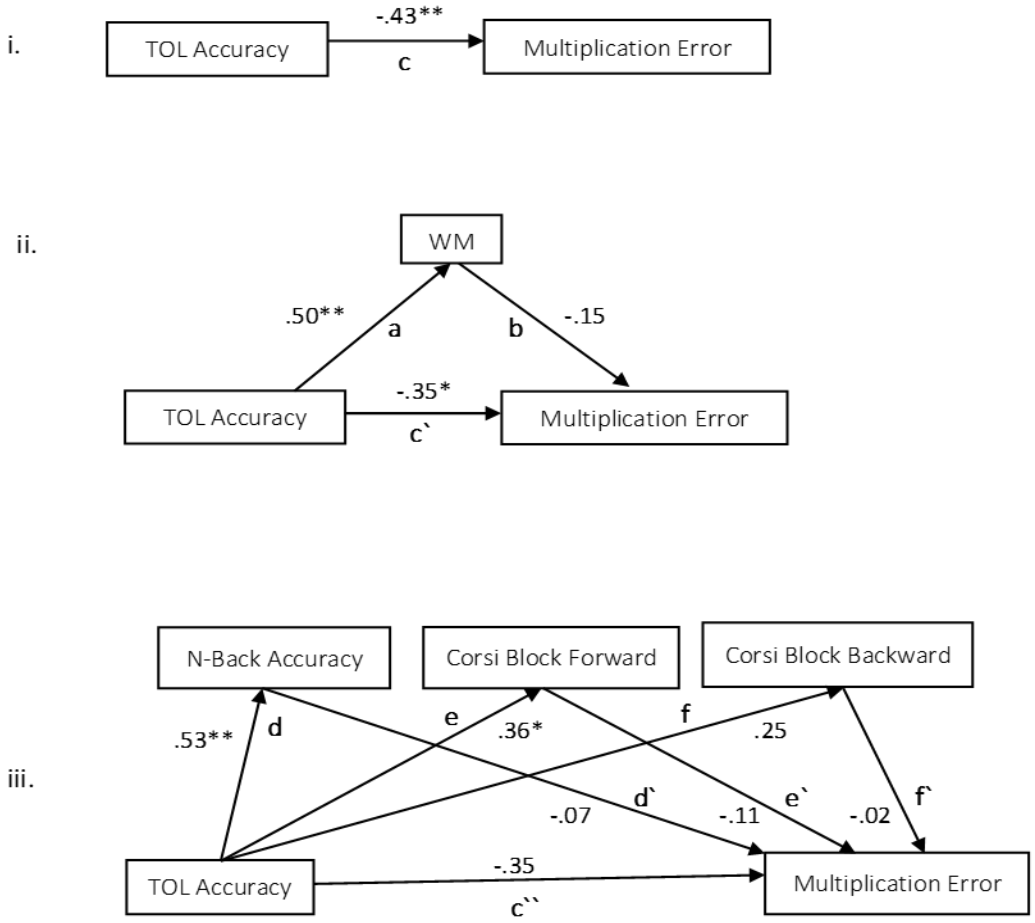

Figure E1. Path analysis model tested the mediator role of aggregated and non-aggregated WM measures in the relationship between the independent variables (TOL Accuracy) and the dependent variable (multiplication errors). (i) Path *c* tested the relationship between the independent variable and the dependent variable without controlling for aggregated and non-aggregated WM measures. (ii) Path *a* tested the relationship between the aggregated WM measures as a mediator and the independent variable and path *c´* tested the relationship between the independent variable and the dependent variable with controlling for aggregated WM measures. (iii) Paths *d, e* and *f* tested the relationships between the non-aggregated WM measures as mediators and the independent variable and path c´´ tested the relationship between the independent variable and the dependent variable with controlling for non-aggregated WM measures. Numbers represent the standardized regression coefficients. Multiplication Error = dependent variable, TOL Accuracy= independent variable (planning accuracy), N-Back = mediator, Corsi-Block Forward = mediator, Corsi-Block Backward = mediator. *$p < .05$. **$p < .01$.

Table E1.

Path Model Statistics for Aggregated and Non-Aggregated WM Measures as Mediators of Planning and Multiplication Errors (%)

Variable	Dependent Variable: Multiplication Errors (%)				
	Path Identifier	*B*	Standardized *B*	*SE*	*p*
TOL[a] Accuracy					
	a	8.51	.50	2.38	.00
	c	-.35	-.43	.12	.00
	c´	-.29	-.35	.13	.03
	c´´	-.28	-.35	.14	.05
WM[b]					
	b	-.01	-.15	.01	.36
N-Back Accuracy					
	d	.37	.53	.09	.00
	d´	-.09	-.07	.20	.67
Corsi-Block Forward					
	e	1.76	.36	.72	.01
	e´	-.02	-.11	.03	.53
Corsi-Block Backward					
	f	1.50	.25	.94	.11
	f´	.00	-.02	.02	.90

Note. $N = 40$. [a]TOL = Tower of London. [b]Aggregated WM measures.

3.2 Study 2: Self-Regulation and Mathematics Performance in German and Iranian College Students

3.2.1. Introduction

Self-regulation is defined as the ability to control one's thoughts, behaviors, or emotions, and enables individuals to adapt their behaviors in accordance with the demands of a situation (e.g., Baumeister & Vohs, 2007, Blair & Ursache, 2011). It includes abilities such as maintaining attention and inhibiting irrelevant information in learning situations, which provides an important foundation for successful academic outcomes (e.g., McClelland & Cameron, 2011). A large body of research connects self-regulation with different academic achievements, such as successful mathematics performance (e.g., Blair & Razza, 2007; Bull & Scerif, 2001; Camahalan, 2006; Fuchs et al., 2006; Gawrilow et al., 2014; Labuhn, Zimmerman, & Hasselhorn, 2010; McClelland, Ponitz, Messersmith, & Tominey, 2010; Otts, 2010; Suchodoletz & Gunzenhauser, 2013; Zimmerman, 1990). For instance, college students with better self-regulation abilities measured by self-reports have been shown to respond more rapidly in mathematics tasks, which could be because of their enhanced ability to ignore distracting thoughts and concentrate on the task (Nemati et al., 2017). In contrast, students without adequate self-regulatory skills are more likely to experience difficulties in mathematics performance. For example, students who struggle with self-regulation, such as students with attention deficit/hyperactivity disorder (ADHD) have more difficulty with mathematics at school (e.g., Frazier et al. 2007; Zentall, 2007).

Previous studies have indicated that self-regulation can contribute to mathematical performance by suppressing distracting thoughts or information whilst mathematics problems are solved (e.g., Gawrilow et al., 2011; Nemati et al., 2017), and through different cognitive components of self-regulation such as inhibitory control (e.g., Hofmann, Friese, Schmeichel, & Baddeley, 2011; McClelland & Cameron, 2011). For instance, solving complex multiplication problems requires ignoring distracting thoughts to remain focused on the task and selecting the correct solutions while suppressing alternative ones (e.g., neighboring solutions in the multiplication table) that can interfere with the retrieval of a desired solution (e.g., “42” can interfere with retrieving the answer to “6 × 8”; cf. Domahs et al., 2006, 2007).

However, the relationship between self-regulation and mathematics performance might vary across different contexts. Recent studies demonstrated that self-regulation is a context-specific construct (e.g., Keller, et al., 2004; Lamm et al., 2017; Suchodoletz, Uka, & Larsen, 2015), suggesting that context can influence self-regulation displayed in different situations. For instance, the different parenting styles of European American and Puerto Rican mothers resulted in different patterns of self-regulation development during childhood (Carlson & Harwood, 2003): in the European American context, mothers expected their children to alter their behavior to match their individual goals, while Puerto Rican mothers asked their children to adjust their behavior in accordance to the society.

These findings are in line with the theoretical framework of Markus and Kitayama (1991), suggesting independent and interdependent contexts, which can influence self-regulation. Independent contexts focus on autonomy and individual goals, whereas interdependent contexts are associated with being in harmony with the group and the community goals. Accordingly, self-regulation processes in an independent context are directed towards influencing the environment and other people in line with an individual's goals, while in interdependent contexts they focus on adjusting one's behavior to the expectations of others to maintain fit with the group (Trommsdorff, 2009). For instance, the results of a recent cross-cultural study (Lamm et al., 2017) revealed that the development of self-regulation and self-regulatory strategies used by children can be different in independent and interdependent contexts. They showed that while German mothers emphasized autonomy and individual goals of their children, Cameroonian mothers expected their children to behave in harmony with society. Thus, German children's self-regulation was motivated by a different goal (i.e., autonomy in Germany vs. parents' expectations and group harmony in Cameroon) and for the same reason, German children might have used different self-regulatory strategies than their Cameroonian peers to do the self-regulation task.

Previous studies have showed that independent contexts are a core characteristic of Central European and North American countries, while interdependent contexts prevail in Asian and Latin American countries (e.g., Higgins, Pierro, & Kruglanski, 2008; Trommsdorff, 2009). In the same line, individualism and autonomy are valued in Germany, while collectivism and group harmony are respected in Iran (Hofstede, 1984). Therefore, Germany and Iran provide two

different contexts with distinct environmental characteristics that can affect self-regulation and its correlates.

However, although self-regulation has been frequently shown to have a context-sensitive nature (Trommsdorff, 2009; see also the review by Jaramillo, Rendón, Muñoz, Weis, & Trommsdorff, 2017), less is known about the relationship between self-regulation and academic achievement, such as mathematics performance, across different countries and the existing results in children are rather scarce and heterogeneous. On the one hand, results of a cross-cultural study in preschool children demonstrated that the associations between different components of self-regulation and mathematics performance were largely similar between Chinese and North American children (Lan, Legare, Ponitz, Li, & Morrison, 2011). They discussed that their finding might be due to the similarities in the associations between different cognitive components of self-regulation in distinct contexts. On the other hand, results of a longitudinal study investigating the application of self-regulatory strategies in educational settings, showed that many of the self-regulatory strategies used by Italian students did not predict the academic achievement as they did in American students (Nota, Soresi, & Zimmerman, 2004). Researchers examined the self-regulatory strategies adopted by Italian students during the final year of high school and their academic achievement in pursuing further education at the University and compared their results with previous studies in American students. In the same vein, but in contrast to previous studies in Western countries, results of another study on Chinese students revealed no relationship between self-regulation and mathematics achievement in Chinese high school students (Rao, Moely, & Sachs, 2000). The authors suggested that self-regulatory strategies motivated by Chinese attitudes towards academic achievement and parents' expectations could not predict mathematics performance in Chinese high school students. Therefore, self-regulatory strategies adopted by students might not be equally important in predicting mathematics achievements across different countries. Altogether, it seems that independent and interdependent contexts can potentially impact the relationship between self-regulation and mathematics performance. Furthermore, differences in self-regulatory skills across different countries can persist in adolescence (e.g., Ellefson et al., 2017), suggesting that context may influence self-regulation and its subsequent relationship with future academic, in particular, mathematics performance. Therefore, the aim of the present study

was to examine whether the relationship between self-regulation and mathematics performance varies between German and Iranian college students.

Additionally, field of study was considered as another context beside the country that could influence the relationship between self-regulation and mathematics performance in college students. It has been shown that individuals need more self-regulation when doing difficult tasks (e.g. Kanfer & Ackerman, 1989; Steele-Johnson, Beauregard, Hoover, & Schmidt, 2000) and solving mathematics problems might be less difficult for students of math-related fields, as compared to students of less math-related fields. Accordingly, context of field of study might affect the relationship between self-regulation and mathematics performance: the relationship between self-regulation and mathematics performance was expected to be weaker in students of math-related fields, such as Engineering/Informatics, as they are assumed to need less self-regulation to solve the mathematics problems than students of less math-related fields, such as Human Sciences. Therefore, the context-effect of field of study was taken into account in the present study as it can influence the students' mathematics performance and hence alter its relationship with self-regulation.

To sum up, in the present study, we examined whether the relationship between self-regulation and mathematics performance differs in German and Iranian college students as independent and interdependent contexts can differentially affect self-regulation and its correlates. Furthermore, we expected that the relationship between self-regulation and mathematics performance is weaker in students of math-related fields, such as Engineering/Informatics, than in students of less math-related fields, such as Human Sciences, because less self-regulation is needed for doing less difficult tasks.

3.2.2. Methods

Participants

Participants were 40 German[2] (33 females, age: M = 20.95 years, SD = 1.08) and 44 Iranian (19 females, age: M = 20.80 years, SD = 1.32) undergraduate students. The German participants were recruited from the University of Tübingen in south Germany and Iranian participants were from the University of Tehran, Iran. All participants were native speakers with no immigration backgrounds. The entire data of the participants were analyzed anonymized (i.e.,

[2] This study used part of the data of the German participants that was published by Nemati et al., 2017

using personal codes instead of names). Detailed characteristics of both German and Iranian students are depicted in Table 1.

Measures

Background characteristics, consisting of field of study, math score in the University entrance exam, math self-concept, expectancy of success, and demographics of the participants (gender, age, nationality, citizenship, mother tongue, language spoken at home) were collected with a background questionnaire. The questions of the background questionnaire, except the questions of math self-concept, were developed by the authors. Math self-concept was assessed by four questions (e.g., "I am good at mathematics.") based on the SDQ (Self Description Questionnaire) III (Marsh, 1992; German translation: Schwanzer, Trautwein, Lüdtke, & Sydow, 2005).

Self-Regulation

Participants' self-regulation was assessed by using self-reports. Participants were asked to fill out the Brief Self-Control Scale (BSCS; Tangney, Baumeister, & Boone, 2004; German translation: Bertrams & Dickhäuser, 2009). The BSCS consists of 13 items targeting thought control, impulsive response control, action persistence, and action monitoring (e.g., "I wish I had more self-discipline."). The response format was a 5-point Likert-type scale ranging from 1 (*completely true)* to 5 (*completely untrue*). Nine items were reverse-coded and the total score was the sum of the responses of all items, with higher sum scores representing more self-regulation. In the present study, the questionnaire showed sufficient internal consistency (in German students: Cronbach's α = .86; in Iranian students: Cronbach's α = .70).

Mathematics performance

Mathematics performance was assessed by using the complex multiplication test, consisting of 48 complex multiplication problems. The complex multiplication problems entailed one-digit times two-digit problems with two-digit solutions (e.g., 4 x 19 = 76; for further details, see Nemati et al., 2017). The complex multiplication problems and their solutions were presented in a computerized verification task, programmed with the PsychoPy software (Peirce, 2009). Half of the presented solutions were correct, and the other half were incorrect. The task started with eight practice trials. All trials were presented in the center of the screen in a fixed order. The problems and their solutions were presented at the same time after the 500 ms fixation point and

remained on the screen until a response was given by the participant, or 6000 ms had passed. Participants responded by pressing the green or red keys (*L* and *A* on a German keyboard) for correct and incorrect solutions, respectively. The response keys were counterbalanced across participants. Except for practice trials, all trials were presented without feedback.

Procedure

The study in Germany was part of a larger project consisting of two testing sessions, each lasting about 2 hrs, aimed at examining the effects of self-regulatory training on the academic performance of young adults. For their participation, German participants received either course credits or 8 Euro per hour. The study in Iran aimed to investigate the relationship between self-regulation and mathematics performance in college students and consisted of filling out the background and BSCS questionnaires plus answering the complex multiplication test. Iranian participants were offered chocolates for their approximately 10 min participation in the study. First, all participants received detailed information about the study and later gave their written informed consent to participate in the study. The testing session took place in a laboratory in Germany or in an empty classroom of the University of Tehran in Iran. For the variables reported here, each participant was tested individually in a single session. First, all participants were asked to fill out the computerized version of the questionnaires consisting of background questionnaire and BSCS items. Subsequently, they were asked to perform the computerized complex multiplication task which lasted about 5 min. Participants received a detailed written instruction emphasizing the importance of both speed and accuracy of the responses in the complex multiplication task.

The German translation of the BSCS (Bertrams & Dickhäuser, 2009) was used in Germany. The original English version of the BSCS was translated into Farsi by two bilingual PhD students from the Psychology field and one bilingual PhD student from outside the field using a well-established method of forward- and backward-translations, following the guidelines from the World Health Organization (WHO, n.d.).

Analysis

In the present study, better performance in the complex multiplication test was indicated by shorter response times (RTs) and lower error rates (ERs). Multiplication RTs of the participants were defined by the time intervals between the presentation of the multiplication

problems on the screen and the responses of the participants, measured by pressing the keys of the computer keyboard. Only RTs of correct responses were considered in the analyses. Moreover, RTs shorter than 200 ms were excluded, and subsequently RTs which were more or less than ±3 SD around the individual mean were excluded continually until no more outliers remained (see: Nuerk, Weger, & Willmes, 2001, and follow-up papers for the same method). Accordingly, about 0.11% of the RTs of the German students and 0.20% of the RTs of the Iranian students were excluded. Furthermore, four trials were excluded from the data of the German students as they were presented with wrong solutions in the complex multiplication task.

Multiplication ERs of the participants were defined as the proportion of incorrect responses. ERs are briefly reported in the descriptive statistics (Table 1) but not considered for the further statistical analyses because the performance of German and Iranian students indicated a ceiling effect, as they made few errors in the complex multiplication task (see Table 1 and Appendix A). Finding a ceiling effect in multiplication performance is not surprising as highly educated adults often perform at above-average levels in mathematics tasks (e.g., Karolis et al., 2011; Siegler & Opfer, 2003).

Relationship between self-regulation and multiplication performance in German and Iranian students

First, to test the effect of self-regulation on multiplication performance, a separate linear regression analysis was conducted for each subsample (i.e., German students, Iranian students). In German students, the linear regression analysis was calculated with self-regulation as predictor and mean multiplication RTs as outcome variable. The linear regression analysis in Iranian students was conducted with self-regulation, field of study, and the interaction between self-regulation and field of study as predictors and mean multiplication RTs as the outcome variable. In the second step, to compare the relationship between self-regulation and mathematics performance in Germany and Iran, the linear regression analysis was calculated with self-regulation, nationality/country, and the interaction between self-regulation and nationality/country as predictors and mean multiplication RTs as the outcome variable.

Effect of field of study on the relationship between self-regulation and multiplication performance in Iranian students

The effect of field of study was not tested in the German students as all of them were students of Human Sciences. However, about half of the Iranian students were studying Human Sciences, while the other half were students of Engineering/Informatics (see Table 1). Therefore, in the first step, the interaction between self-regulation and field of study (dummy coded) was tested in an aforementioned linear regression analysis in Iranian students. After finding a significant interaction between self-regulation and field of study among Iranian students, in the second step, simple slope analyses (Aiken & West, 1991; Rogosa, 1981) were used to further investigate the nature of this interaction effect. All continuous variables were standardized for the simple slope analyses. The level of significance was set to $\alpha < .05$ for all analyses.

3.2.3. Results

Descriptive Statistics

Descriptives and test statistics for the background characteristics and the study measurements of German students, Iranian students, and the entire sample are presented in Table 1[3]. In case of non-normally distributed variables Mann-Whitney-U test, and for normally distributed variables *t*-test and Chi² test, were used. German and Iranian students did not differ in most of the background characteristics, such as age, math self-concept, and math score in the University entrance exam. However, the number of German female participants was significantly higher compared to Iranian students, $X^2(1) = 6.27$, $p = .012$. Additionally, expectancy of success of German students was significantly lower than that of Iranian students, $U = 567.5$, $p = .003$.

Self-regulation of German students did not differ from self-regulation of Iranian students, $t(82) = 0.73$, $p = .461$. However, German and Iranian students did differ in their multiplication performance: German students were slower, $U = 459.5$, $p < .001$ and made more errors, $t(82) = -4.53$, $p < .001$ as compared to Iranian students.

[3] The correlation matrix for the background characteristics of the German and Iranian students is presented in Appendix B for the interested reader.

Table 1.
Descriptive and Test Statistics of Background Characteristics and Study Measurements

Variable	German		Iranian		Diff	Entire Sample	
	n	*M* (*SD*)	*n*	*M* (*SD*)	*p*	*n*	*M* (*SD*)
Age (years)	40	20.95 (1.08)	44	20.80 (1.32)	.674[a]	84	1.87 (1.21)
Gender, female	33		19		**.012[b]**	52	
Field of study							
Human Sciences	40		20			60	
Engineering/ Informatics	0		24			24	
Math self-concept	40	2.75 (0.84)	44	2.91 (1.18)	.256[a]	84	2.83 (1.03)
Expectancy of success	40	2.77 (0.73)	44	3.25 (0.90)	**.003[a]**	84	3.02 (0.85)
Math score in the University entrance exam	40	2.35 (0.77)	44	2.45 (0.79)	.608[b]	84	2.40 (0.78)
Low	7		8			15	
Moderate	12		8			20	
High	21		28			49	
Self-Regulation	40	41.42 (8.74)	44	42.66 (6.70)	.467[c]	84	42.07 (7.71)
Multiplication performance							
ER	40	0.18 (0.11)	43	0.11 (0.10)	**<.001[a]**	83	0.15 (0.11)
RT (s)	40	3.10 (0.46)	44	2.51 (0.63)	**<.001[c]**	84	2.79 (0.66)

Note. [a]Mann-Whitney-U test, [b]Chi^2-test, [c]*t*-test. Bold *p*-values depict $p < .05$.

Relationship between Self-Regulation and Multiplication RT in German and Iranian Students

To test the relationship between self-regulation and multiplication RT, two series of linear regression analyses were conducted separately in German and Iranian students. The first linear regression analysis was conducted for RT as dependent variable and self-regulation as predictor in German students. Regression analysis revealed that self-regulation predicted faster multiplication RT in German students (see Table 2 and Figure 1). The second linear regression analysis was conducted for multiplication RT as dependent variable and self-regulation, field of study, and the interaction between self-regulation and field of study as predictors in Iranian students. The results showed that there is no significant relationship between self-regulation and

multiplication RT in Iranian students (see Table 3 and Figure 1), whereas field of study and the interaction between self-regulation and field of study predicted multiplication RT (see Table 3). As all German students were in the same field of study, field of study and the interaction between self-regulation and field of study were not considered as predictors in the first linear regression model in German students (see Table 2). Furthermore, the interaction between self-regulation and nationality/country was tested in a linear regression analysis and the result indicated that the relationship between self-regulation and mathematics performance of German students did not differ significantly from that of Iranian students (Appendix C) nor from those Iranian students studying Human Sciences (see Table 4). Moreover, although German and Iranian students significantly differed in gender (see Table 1), our result was not explained by the gender differences between the two countries (see Appendices B, D, and E).

Table 2.

Regression Analysis Predicting Multiplication RT from Self-Regulation in German Students

Predictor	*b*	SE *B*	*t*	*p*
Self-Regulation	-0.34	0.15	-2.26	**.029**

Note. $n = 40$. $R^2 = .12$, $F(1, 38) = 5.12$, $p = .029$. All variables are standardized
Bold *p*-values depict $p < .05$.

Table 3.

Linear Model of Predictors of Multiplication RT in Iranian Students

Predictor	*b*	*SE(B)*	*t*	*p*
Constant	-0.52	0.16	-3.31	**.002**
Self-Regulation	0.12	0.16	0.74	.463
Field of Study	1.19	0.23	5.04	**<.001**
Self-Regulation × Field of Study	-0.54	0.24	2.26	**.029**

Note. $n = 44$. $R^2 = .44$, $F(3, 40) = 10.35$, $p < .001$. All variables are standardized and Field of Study was dummy coded. Bold *p*-values depict $p < .05$.

Table 4.
Linear Model of Predictors of Multiplication RT in German and Iranian Students of Human Sciences

Predictor	*b*	*SE(B)*	*t*	*p*
Constant	-0.15	0.21	-0.70	.488
Self-Regulation	-0.56	0.25	-2.21	**.031**
Nationality/Country	0.24	0.26	0.92	.361
Self-Regulation × Nationality/Country	0.24	0.29	0.84	.402

Note. $n = 60$. $R^2 = .17$, $F(3, 56) = 3.91$, $p = .013$. All variables are standardized and Nationality/Country was dummy coded. Bold *p*-values depict $p < .05$.

Figure 1.

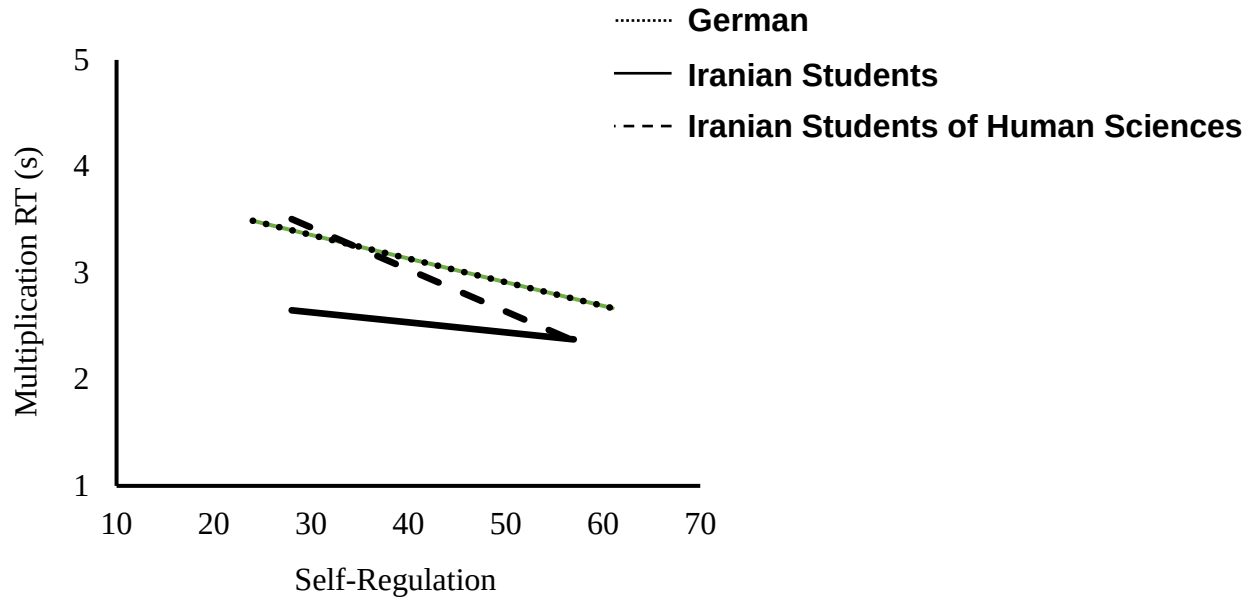

Figure 1. Linear regression trend lines testing the relationship between self-regulation as predictor and multiplication RT as the dependent variable in three different samples: German students, Iranian students, Iranian students of Human Sciences.

The Effect of Field of Study on the Relationship between Self-Regulation and Multiplication RT in Iranian Students

The effect of field of study on the relationship between self-regulation and multiplication RT was tested by conducting a linear regression analysis with RT as dependent variable and self-regulation, field of study (dummy coded), and the interaction between self-regulation and field of

study as predictors in Iranian students (see Table 3). The interaction between self-regulation and field of study was significant in the Iranian students, indicating that field of study influenced the relationship between self-regulation and multiplication RT (see Table 3). To figure out the nature of the effect of field of study on the relationship between self-regulation and multiplication RT, a simple slope analysis was conducted.

Simple slope analysis in Iranian students

As shown in Table 5 and Figure 2, there is a significant negative relationship between self-regulation and multiplication RT in Iranian students of Human Sciences (b= -0.42, p = .021), but not in Iranian students of Engineering/Informatics (b= 0.12, p = .463). The coefficient of the simple slope in Human Sciences reflected a decreasing trend, thus the higher the self-regulation the better the students of Human Sciences performed in the complex multiplication task. Moreover, the effect of field of study was greater in students with lower self-regulation and there was no difference between fields of study for students with high self-regulation (see Figure 2).

Table 5.

Simple Slope Analysis in Iranian Students

Field of Study	*b*	*SE(B)*	*t*	*p*
Human Sciences[a]	-0.42	0.17	-2.41	**.021**
Engineering/Informatics[b]	0.12	0.16	0.74	.463

Note. [a]n = 20,[b] n = 24. All variables are standardized. Bold p-values depict $p < .05$.

Figure 2.

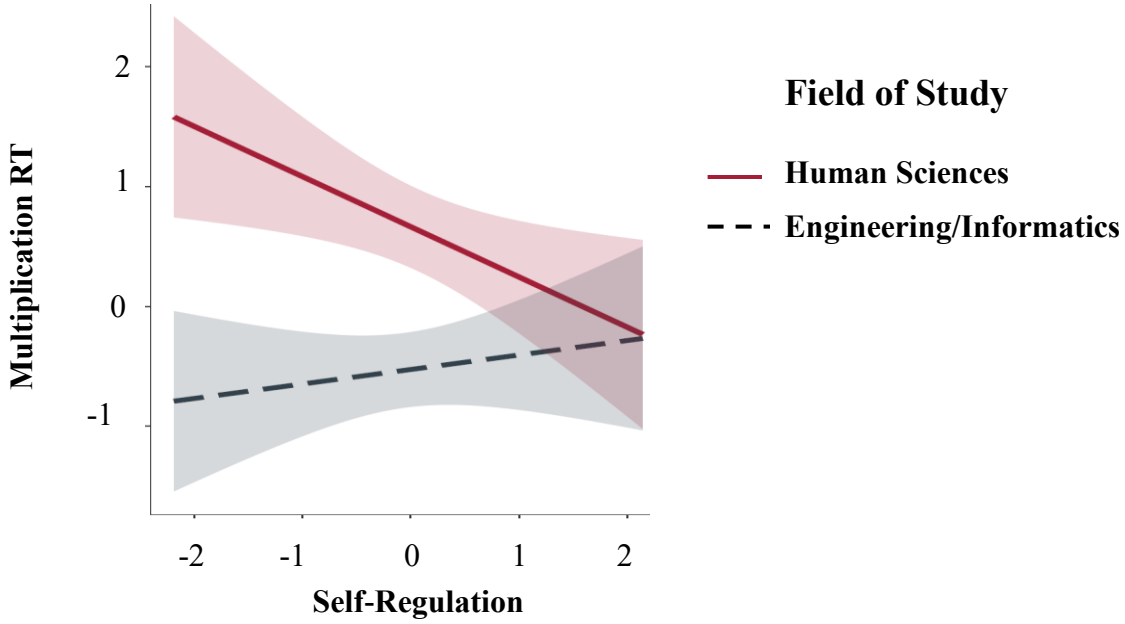

Figure 2. Simple slopes equations of the regression of multiplication RT on self-regulation in Human Sciences and Engineering/Informatics fields of study in Iranian students. All variables are standardized.

3.2.4. Discussions

The present study compared the relationship between self-regulation and mathematics performance between students in two different countries (i.e., Germany vs. Iran) and – within Iran – for two different fields of study. As presupposed for independent and interdependent cultures, the relationship between self-regulation and mathematics performance differed between German and Iranian college students: self-regulation predicted multiplication RT in German students, whereas there was no significant relationship between self-regulation and multiplication RT in Iranian students. However, when the field of study was taken into account in Iranian students, self-regulation predicted multiplication RT in those Iranian students studying less math-related fields (i.e., Human Sciences) but not in students of math-related fields (i.e., Engineering/Informatics). Therefore, as expected, the relationship between self-regulation and mathematics performance was weaker in Iranian students of Engineering/Informatics as compared to Iranian students of Human Sciences. This might be because the complex

multiplication test seemed to be less difficult for the Iranian students of Engineering/Informatics compared to the Iranian students of Human Sciences, therefore, these students might need less self-regulation to solve the problems. The complex multiplication test seemed to be less difficult for the Iranian students of Engineering/Informatics as they performed better (i.e., they had significantly shorter RT and less ER) than Iranian students of Human Sciences (see Appendix E). Moreover, math-self-concept was significantly higher in Iranian students of Engineering/Informatics than Iranian students of Human Sciences (see Appendix E) and significantly correlated with shorter RTs (see Appendix B), suggesting that Iranian students of Engineering/Informatics believed in their self-ability to do well in mathematics. Thus, Iranian students of Engineering/Informatics might have used less self-regulation while doing complex multiplication test as the test was less difficult for them. This is consistent with previous studies revealing that individuals need more self-regulation while solving challenging tasks (e.g. Kanfer & Ackerman, 1989; Steele-Johnson, Beauregard, Hoover, & Schmidt, 2000). For instance, it has been shown that task difficulty can moderate the effect of self-regulation on performance (Steele-Johnson, Beauregard, Hoover, & Schmidt, 2000). The authors found that when the cognitive load of the task is high, individuals have to decide how to allocate their limited attentional resources to the task, therefore, they are in need of more self-regulation. In the same vein, no difference was found between fields of study for Iranian students with high self-regulation in the present study, suggesting that individuals with high self-regulation can perform well independent of task difficulty as they do not need higher self-regulation when facing challenging tasks. However, it should be noted that the effect of field of study on the relationship between self-regulation and mathematics performance was tested only in the Iranian students, therefore, could not be generalized to other national groups.

Taken together, the results showed that the relationship between self-regulation and mathematics performance generally differed between German and Iranian college students. However, the differences we observed can be explained by differences in the context of field of study than in the context of country, as is further supported by the fact that when only the students of Human Sciences are compared, the observed association between self-regulation and mathematics is similar in both countries. This finding is in line with a cross-cultural study by Lan and colleagues (2011), described earlier, that assessed the cognitive components of self-regulation, such as inhibition and attentional control, and examined their associations with

simple and complex mathematics performances in Chinese and North American children. Their results demonstrated that the relationship between different cognitive aspects of self-regulation and both simple and complex mathematics performance are similar in Chinese and North American children. The authors argued that the neurobiological and genetic factors which determine the strength of associations between various components of self-regulation may be similar in distinct contexts, therefore, their subsequent contribution to academic performance is also more likely to be consistent across countries. However, Chinese children outperformed North American children in some of the self-regulation tasks such as inhibition and attentional control. The authors ascribed these performance differences in self-regulation tasks to variances in specific cultural practices in educational settings during kindergarten and primary school. For instance, it has been shown that Asian children receive more intensive practice in controlling their attention and behavior in kindergarten or the classroom than North American children (e.g., Chen et al., 1998; Kwon, 2004; Lan et al., 2009). Therefore, it seems that although different aspects of self-regulation may be learned and used differently in interdependent and independent countries, their interrelations with each other and their association with mathematics performance remains similar. This interpretation is in line with the idea that both independent and interdependent systems exist and are essential in each country, but there might be differences among the countries in the strength of their application (e.g., Harwood et al., 2001; Leyendecker et al., 2002; Jin-Schmidt, 2014). In the same vein, both independent and interdependent self-regulation processes may exist in Germany and Iran to different degrees, but this may not significantly influence their level of contribution to the mathematics performance.

However, our finding is in contrast with previous studies, connecting the academic achievement gap between students from different countries to the effect of context on self-regulation. For instance, in a longitudinal study by Nota and colleagues (2004) which was explained earlier, many of the self-regulatory strategies that predicted academic achievement in American students did not directly predict academic achievement in Italian students. However, compared to the study by Nota and colleagues (2004), the effect of various self-regulatory strategies was not investigated in the present study and contexts as well as measures of self-regulation and academic achievement differ from their study. Another important reason why, unlike our study, they found differences in the relationship between self-regulation and academic achievement across two countries, might be the effect of samples: Italian students were high

achievers who are more likely to self-regulate than typical populations of students and in this sense differed from the American students and from the students of Human Sciences in facing mathematics test in our research. Furthermore, with regard to the confounding effect of field of study on the predictive validity of self-regulation, it is possible that the discovered differences in their study might have been due to lack of control for the effect of field of study. Therefore, careful sample selection considering field of study of students is highly recommended for future cross-cultural research to avoid the possibility of interpreting the effect of field of study as cultural effects.

Limitations

The current research has some limitations worth noting. First, the effect of field of study was not examined in German participants as they were students of the same field of study (i.e., Human Sciences). Therefore, it could only be examined in the Iranian sample. Future studies should also consider other fields of study such as Engineering/Informatics in Germany to make it easier to differentiate between effects of context and effects of field of study on the relationship between self-regulation and mathematics performance. Second, there might be structural and cultural variations in educational systems such as different grading systems or teachers' expectations, as well as academic motivation of students within and between nations that may differentially influence self-regulation and its relationship with academic performance. Therefore, we view this study only as a starting point for investigating the impact of independent and interdependent cultures on the relation between self-regulation and math performance. Future studies conducted in other independent or interdependent cultures should clarify whether the observed results are really due to this cultural difference or to other educational or cultural differences, which are particular to the specific countries studied here. Third, self-regulation consists of several components such as cognitive, behavioral, and emotional aspects that are differentially related to mathematics performance and their effects should be investigated individually in the future research. Forth limitation is the small sample size of the present study that may preclude a definitive statement for the present study. The last, but not least, important limitation is construct validity in the present study, as our research measurement for assessing self-regulation was designed and validated for Western countries. The problem is that in self-reports, participants of one cultural context may interpret the words differently and compare themselves with different standards than those in another cultural context (e.g., Heine, Lehman,

Peng, & Greenholtz, 2002). In our study, the internal consistency of the self-regulation self-report in Iranian students is sufficient for the present study and in line with previously reported findings in Eastern countries such as China (Cronbach's α = .75; Unger, Bi, Xiao, & Ybarra, 2016), however, it should be also noted that it is relatively low, which can be due to either a reliability or homogeneity problem. In the future, international researchers should strive for a transcultural self-regulation scale, which can be used in Western and non-Western cultures with high reliability and validity.

3.2.5. Conclusion

In conclusion, our results showed that the relationship between self-regulation and mathematics performance is similar in German and Iranian college students when the effect of field of study is controlled in Iranian students. In addition, the effect of field of study on the relationship between self-regulation and mathematics performance was highlighted in the present study. The results suggested that previously discovered differences in the relationship between self-regulation and academic performance between countries might be due to an effect of field of study. Therefore, the possible confounding effect of field of study should be considered in cross-cultural, but also single-culture studies when the relationship between self-regulation and mathematics performance is examined.

Appendix A

Ceiling/Floor Effect for Multiplication ER

Sample	*n*	*M (SD)*	*K-S*[a]	*Skewness*	*Kurtosis*
German students	40	0.18 (0.11)	.03	1.02	1.18
Iranian students	44	0.11(0.10)	.001	1.50	1.95

Note. [a]Kolmogorov-Smirnov p-values.

Appendix B

Correlation Matrix in German and Iranian Students

Table B.1.

Correlations between Background Variables, Self-Regulation, and Multiplication Performance in German Students

Variable	1	2	3	4	5	6	7
1. Age	-						
2. Gender	-.10	-					
3. Math self-concept	-.41*	.38*	-				
4. Expectancy of success	-.30	.32*	.61*	-			
5. Math score in the University entrance exam	-.19	.22	.65*	.32*	-		
6. Self-Regulation	.07	-.21	-.07	.08	-.05	-	
7. Multiplication RT (s)	.08	-.18	-.29	-.32*	-.12	-.34*	-

Note. $n = 40$. *Correlation is significant at the 0.05 level (2-tailed).

Table B.2.

Correlations between Background Variables, Self-Regulation, and Multiplication Performance in Iranian Students

Variable	1	2	3	4	5	6	7
1. Age	-						
2. Gender	.07	-					
3. Math self-concept	.15	.09	-				
4. Expectancy of success	.10	.09	.33*	-			
5. Math score in the University entrance exam	.11	.10	.67*	.43*	-		
6. Self-Regulation	.09	-.03	.13	-.13	.11	-	
7. Multiplication RT (s)	-.06	-.04	-.56*	-.63*	-.61*	-.10	-

Note. $n = 40$. *Correlation is significant at the 0.05 level (2-tailed).

Appendix C

Interaction between Self-regulation and Nationality

Predictor	*b*	*SE(B)*	*β*	*t*	*p*
Constant	2.91	0.58		5.02	**.000**
Self-Regulation	-0.01	0.01	-.11	-0.70	.486
Nationality/Country	1.11	0.74	.84	1.51	.136
Self-Regulation x Nationality/Country	-0.01	0.02	-.42	-0.74	.459

Note. $N = 84$. Nationality was dummy coded. $R^2 = .24$, $F(3, 80) = 8.63$, $p < .001$.

Bold *p*-values depict $p < .05$.

Appendix D

Linear Model of Predictors of Multiplication RT in the Whole Sample

Table D.1.
Linear Model of Predictors of Multiplication RT in the Whole Sample

Predictor	*b*	*SE(B)*	*t*	*p*
Constant	0.22	0.13	1.65	.103
Self-Regulation	-0.30	0.13	-2.34	**.021**
Gender	-0.56	0.21	-2.61	**.010**
Self-Regulation × Gender	0.14	0.22	0.66	.509

Note. $N = 84$. All variables are standardized and Gender was dummy coded.
$R^2 = .13$, $F(3, 80) = 4.14$, $p = .008$.
Bold *p*-values depict $p < .05$.

Table D.2.
Interaction between Nationality/Country and Gender Predicting Multiplication RT

Predictor	*b*	*SE(B)*	*t*	*p*
Constant	-0.38	0.21	-1.86	.067
Nationality/Country	0.92	0.26	3.54	**.001**
Gender	-0.07	0.27	-0.25	.805
Nationality/Country × Gender	-0.34	0.47	-0.72	.470

Note. $N = 84$. Multiplication RT was standardized. Gender and Nationality/Country were dummy coded. $R^2 = .21$, $F(3, 80) = 7.18$, $p < .001$. Bold *p*-values depict $p < .05$.

Appendix E

Descriptive and Test Statistics of Background Characteristics and Study Measurements in Iranian students of Engineering/Informatics and Human Sciences

Variable	Engineering/Informatics	Human Sciences	Diff
	M (*SD*)	*M* (*SD*)	*p*
Age (years)	21.21 (0.88)	20.30 (1.59)	.031[a]
Gender, female (%)	47	50	.543[b]
Math self-concept	3.58 (0.65)	2.85 (0.98)	.006[a]
Expectancy of success	0.75 (0.44)	0.65 (0.49)	.474[a]
Math score in the	54.67 (14.30)	25.93 (26.27)	<.001[a]
University entrance exam			
Self-Regulation	42.33 (6.66)	43.05 (6.89)	.728[c]
Multiplication performance			
ER	0.05 (0.04)	0.19 (0.11)	<.001[a]
RT (s)	2.17 (0.45)	2.91 (0.58)	<.001[c]

Note. [a]Mann-Whitney-U test, [b]Chi^2-test, [c]*t*-test.
Bold *p*-values depict $p < .05$.

3.3. Study 3: Delay of Gratification Performance of Iranian and German Preschool Children

3.3.1. Introduction

Self-regulation is a multidimensional construct, which describes the ability to monitor and control one's own emotions, thoughts, and behaviors (e.g., Blair & Ursache, 2011; Calkins, 2007). Children's self-regulation is essential as it has been shown that greater self-regulation abilities are associated with better academic performance and fewer emotional and behavioral problems (e.g., Ayduk et al., 2000; Duckworth & Seligman, 2005; Eisenberg et al., 2000). The importance of self-regulation abilities in children is further emphasized by the longitudinal findings showing that self-regulation measured at preschool age is a robust predictor of academic performance in first school year after controlling for children's intelligence (von Suchodoletz, Trommsdorff, Heikamp, Wieber, & Gollwitzer, 2009).

Recent studies indicate that different contexts can influence the development of self-regulation abilities in children (e.g., Keller et al., 2004; Lamm et al., 2018; von Suchodoletz, Uka, & Larsen, 2015; see also the review by Jaramillo, Rendón, Muñoz, Weis, & Trommsdorff, 2017). For instance, the development of self-regulation abilities in children were assessed and compared between Cameroon, Greece, and Costa Rica (Keller et al., 2004). Cameroonian families expected their children to be obedient and fulfill responsibilities in the household, Greek families highly valued the independency and autonomy of their children, and Costa Rican families expected their children to become economically independent but remain emotionally dependent to the family. The authors reported that Cameroonian children showed greater self-regulation abilities than Greek and Costa Rican children when they were asked to comply with adults' requests. However, self-recognition (i.e., being aware of oneself) as one of the underlying processes of self-regulation developed earlier in Greek children. Therefore, it seems that not only the development of self-regulation ability but also the development of processes underlying it might vary across different contexts. Their findings are also relevant to the concepts of *ought-self* and *ideal-self* suggested by Higgins (1998). The *ought-self* represents the attributes that an individual believes a person ought to achieve, whereas the *ideal-self* refers to a desirable state individuals try to achieve themselves. Accordingly, the ought-self goals are related to a

prevention-focused self-regulation which is centered on responsibility and meeting obligations, while the ideal-self goals lead to a promotion-focused self-regulation which is focused on personal accomplishment and success (Higgins, Pierro, & Kruglanski, 2008). Both promotion and the prevention self-regulation systems can exist in every cultural context, but the strength of their application might differ among different contexts. For instance, in the study described above, it has been shown that the prevention-focused self-regulation promoted by Cameroonian parents was used more by Cameroonian children than their Greek and Costa Rican peers (Keller et al., 2004).

In the same line, it has been shown that interdependent and independent contexts (Markus & Kitayama, 1991), influence the development of self-regulation abilities in children. In interdependent contexts, group goals and maintaining fit with the society are highly valued, whereas in independent contexts, individual goals and autonomy are valued higher. Accordingly, self-regulation in interdependent contexts is associated with adjusting one's behavior to the expectations of others to remain in harmony with the group. In independent contexts, self-regulation is related to adapting the environment consistent with an individual's goals (Trommsdorff, 2009). Previous studies have indicated that interdependent contexts tend to prevail in Asian and Latin American countries, whereas independent contexts are dominant characteristic of Central European and North American countries (Higgins et al., 2008; Trommsdorff, 2009).

Despite the context-sensitive nature of the self-regulation, cross-cultural studies comparing self-regulation abilities of children from more interdependent or independent contexts are scarce. Some studies showed that preschool children from Eastern Asian countries outperformed their peers from European and North American countries on self-regulation tasks which required inhibition of predominant responses (e.g., Oh & Lewis, 2008; Sabbagh, Carlson, Moses, & Lee, 2006). Moreover, a cross-cultural study investigating the inhibitory control in children demonstrated that Cameroonian children performed better than their German and Costa Rican peers in an inhibitory control task (Chasiotis, Kiessling, Hofer, & Campos, 2006). Similar results were reported in a cross-cultural study investigating self-regulation abilities in Cameroonian and German preschool children (Lamm et al., 2018). The authors reported that Cameroonian mothers expected their children to behave in accordance with adults' expectations, whereas German mothers promoted independency and autonomy in their children. Consequently,

Cameroonian children regulated their behaviors to fulfill their parents' expectations, while self-regulation in German children was motivated by individual goals and autonomy. Their results revealed that Cameroonian children performed better than their German peers in the self-regulation task and relied on different self-regulatory strategies to control their behaviors (Lamm et al., 2018). Thus, it seems that the development of self-regulatory strategies used by children might differ, depending on whether children grew up in interdependent or independent contexts. However, Cameroon and Eastern countries are very diverse in terms of cultural features (e.g., language, religion, etc.) which makes it difficult to generalize their results to all Eastern countries such as Iran.

In the same vein, Iran as a Middle Eastern country represents a more interdependent context than Germany that is characterized as an independent context (e.g., Hofstede, 1984; Keller & Kärtner, 2013; Tõugu, Tulviste, Kasearu, Talves, & Albert, 2018). Accordingly, Iran and Germany provide two different contexts with distinct environmental characteristics that may affect self-regulation abilities in children. Therefore, the main aim of the present study was to examine whether self-regulation abilities in preschool children differ between Iran and Germany. To the best of our knowledge, self-regulation abilities of preschool children have not yet been approached cross-culturally between Iran/Middle Eastern countries and Germany/European countries by a delay of gratification paradigm.

Delay of gratification is an important aspect of self-regulation which refers to the ability to ignore current desires in order to achieve the long-term goals (Mischel, 1996). The delay of gratification task assesses self-regulation ability in preschool children by creating a situation in which children can choose between having one reward immediately or waiting for an unspecified time and receiving two rewards afterwards (Mischel, 1996). Therefore, successful performance in the delay of gratification task requires self-regulation ability to resist an impulse to take an immediately available reward in order to receive a more-valued reward in the future. The importance of the delay of gratification task in examining self-regulation in preschool children was further supported by a longitudinal study, demonstrating that performance in the delay of gratification task at preschool age predicted academic achievement and social competence ten years later (Shoda, Mischel, & Peake, 1990). Moreover, the delay of gratification task allows for not only investigating delay of gratification ability but also the factors influencing this ability. Accordingly, strategies that facilitate or impede performance in the delay of gratification task

have been investigated in previous studies (for a summary, see Mischel, 2014). Altogether, previous studies suggested that strategies which draw the attention towards the reward (e.g., looking towards the reward or touching it) can facilitate performance, whereas distracting strategies that direct the attention away from the reward (e.g., singing or turning away from the reward) can impede performance in the delay of gratification task (e.g., Eigsti et al., 2006; Manfra, Davis, Ducenne, & Winsler, 2014; Neuenschwander & Blair, 2017; Rodriguez, Mischel, & Shoda, 1989). So far, behavioral strategies influencing performance in the delay of gratification task have been mainly investigated in Western countries and merely once explored cross-culturally. Consistent with previous research in Western countries, this study showed that the reward-oriented strategies hampered performance in the delay of gratification task in both Cameroonian and German preschool children (Lamm et al., 2018). However, German children used more distracting strategies than their Cameroonian peers. The authors argued that the respective behavioral strategies used by the children reflected the characteristics of interdependent and independent contexts. Cameroonian children did not engage in much distracting motoric strategies as they tried to keep in harmony with the situation, while German children used a greater amount of distracting motoric strategies to control the situation and adapt it to their personal desires (Lamm et al., 2018). Therefore, interdepend and independent contexts seem to have influence on self-regulatory strategies used by children in the delay of gratification task.

To sum up, the present study aimed at investigating self-regulation ability and strategy in Iranian and German children by the delay of gratification task. Since independent and interdependent contexts can differentially influence self-regulation abilities of children, the hypothesis of the present study was that Iranian and German children were expected to differ in their performance and behavioral strategies in the delay of gratification task.

3.3.1 Methods

Participants

Iranian children: Altogether 100 Iranian children, recruited in Tehran, participated in the study. Children who cried (n = 4) or called the experimenter to return to the room (n = 4) during the waiting time in the delay of gratification task were excluded. Moreover, children who didn't choose any reward, that is chocolate, due to sickness (n = 2) or a lack of interest (n = 4) were

also excluded from further analyses. Lastly, two children were excluded due to an experimenter's mistake in identifying the rule-breaking behaviors and prematurely stopping the experiment. Consequently, 84 Iranian children (37 girls, age: $M = 4.92$ years, $SD = 0.46$) were included in the analyses. Questionnaires were completed by 60 mothers, 18 fathers, and in six cases by both parents. All children and their parents were born in Iran with Farsi being the only language spoken at home.

German children: In total, 48 German children participated in the study. The German children were recruited from the city of Tübingen and its surrounding areas in southern Germany. Children who cried during the waiting time in the delay of gratification task ($n = 2$) or did not choose any chocolate due to a lack of interest ($n = 1$) were excluded. Additionally, children with immigrant background ($n = 5$) were also not considered for further analyses. As a result, 40 German children (17 girls, age: $M = 4.99$ years, $SD = 0.50$) were included in the analyses. Questionnaires were answered by 32 mothers, seven fathers, and in one case by both parents. All children and their parents were born in Germany and German was the only language spoken at home.

The description of both Iranian and German children who participated in the delay of gratification task is depicted in Table 2. As a proxy for socioeconomic status (SES), parents were asked to reveal their educational level and status of employment (Bradley & Corwyn, 2002; Entwisle & Astone, 1994). Due to substantial differences in the education and school systems of Iran and Germany, the educational level of parents was divided into low (10 or less years of schooling) and high (more than 10 years of schooling). Moreover, in the present study, employment status represented all jobs with salaries and unemployment status includes occupations without salaries such as homemaker.

Measures

Delay of gratification task: The original instruction of the delay of gratification task (Mischel, 2014) was used in the present study with a small adaption: chocolates were used instead of marshmallows because marshmallow was not popular in Iran. First, the children were welcomed by the experimenter and were asked if they would like to participate in the delay of gratification task. Upon their oral consent, they were asked to sit on a kid-sized chair at an empty table and a desk-bell was placed on the table by the experimenter. Next, the children were

instructed to the first rule: whenever the experimenter leaves the room, the children could bring her back by ringing the desk-bell. This first rule was practiced at least three times or until the experimenter was sure that it was well understood. Later, the children were asked whether they liked chocolates. Upon the children's positive answers, they were asked to choose their favorite type from a chocolate box, consisting 5 different mini-chocolate bars. Subsequently, they were asked if they would prefer one or two of their favorite chocolate bar. If they answered one, they got one chocolate and the testing was terminated, otherwise, three chocolate bars were unwrapped and placed on a white empty plate in front of the children. Two chocolate bars were placed on the right side of the plate and one was placed on the left side. Then, the children were informed that the experimenter would walk out the room for a while to set up a game for another child. Subsequently, they were explained the following instruction by the experimenter: "If you wait without ringing the bell, eating or licking the chocolates, and standing up until I come back by myself, you will get two chocolates, otherwise, you will get only one chocolate". Importantly, the children did not know for how long they would have to wait for the experimenter to return and for them to receive two chocolates bars. The experimenter made sure that the children understood the instruction by asking questions about the instruction and rule-breaking behaviors (i.e., ringing the desk-bell, eating/licking the chocolates, and standing up). The children were reminded that whenever they wanted to stop waiting, they can ring the desk-bell and bring the experimenter back to the room.

Finally, the children were left alone in the room. The children's behaviors during the waiting time were recorded by GoPro camera Hero4 ® which was connected to a smartphone. Therefore, the children's behaviors during the waiting time could be monitored by the experimenter via the smartphone from outside the room. If the child felt uncomfortable or distressed because of being alone in the room, the experimenter stopped the test immediately and re-entered the room (this occurred with eight Iranian and two German children who cried or called the experimenter during the waiting time).

The delay of gratification task was terminated upon the incidence of rule-breaking behaviors. Otherwise, the experimenter returned to the room after 25 min and the children were thanked and offered two chocolate bars at the end of the testing session. Performance in the delay of gratification task was defined as (1) waited 25 min (2) did not wait 25 min and also

assessed by the time duration the child waited for the second chocolate bar before showing the rule-breaking behaviors (i.e., waiting time).

Control questions. After the delay of gratification task, the experimenter asked the children the following control questions: (1) Can you tell me what you have been waiting for? (2) How much do you like the chocolate bars? Responses to the first question were defined as 0 (when the child did not mention "chocolate") and 1 (when the child mentioned "chocolate"). Answers to the second question ranged from 1 (not at all) to 3 (very much) and aimed at assessing craving for chocolate. Furthermore, parents or kindergarteners were asked to reveal the last meal time of the children to check whether the amount of time since the last meal might explain the difference between children who managed to wait 25 min for the second chocolate bar and those who did not.

Behavioral strategies. The children's behavioral strategies during the waiting time were rated with an adaptation of the rating scale developed by Ravenswaaij and colleagues (Ravenswaaij, Mulder, Verhagen, & Leseman, in press). The chocolate bars or the desk-bell which could terminate the waiting period were defined as rewards. The children's strategies were rated in three main domains: visual, verbal, and motor. In all three domains, behaviors drawing attention towards the reward were rated as focusing strategies, whereas behaviors directing attention away from the reward were rated as either distracting or withholding strategies. Distracting strategies such as looking away from the reward were used to be less engaged with the reward. Withholding strategies were a form of distracting strategies that included behaviors that children can use to actively stop themselves from touching the reward such as holding their hands. The original rating scale (Ravenswaaij et al., in press) was developed to assess toddlers' behaviors during the waiting time in the delay of gratification paradigm. Therefore, the rating scale was adapted for the present study to assess the behavioral strategies of preschool children in the delay of gratification task: 12 items of the original rating scale were excluded as they were either not relevant to our task (e.g., "Talks about the object to someone else") or difficult to be observed in our videos (e.g., "Sits on own hands"). Moreover, the rule-breaking behavior of the original rating scale (i.e., "Touches the reward") was added as a focusing strategy to the adapted rating scale because it could draw the attention towards the reward. The adapted rating scale with behavioral domains is presented in Appendix A.

Self-control: The children's dispositional capacity of self-control was assessed with the German parent rating-version of the Brief Self-Control Scale (BSCS; Rauch, Gawrilow, Schermelleh-Engel, & Schmitt, 2014) which is a translation and adaptation of BSCS (Tangney, Baumeister, & Boone, 2004). The German parent-rating version of the BSCS was translated into Farsi and used in Iran. The scale consists of 13 items targeting action persistence, thought control, and overcoming of negative habits (e.g., "My child is good at resisting temptation."). Every item was rated by parents on a 5-point Likert-type scale ranging from 1 (*not at all)* to 5 (*completely*). Nine items were reverse-coded and the total score was the sum of the responses of all items, with higher sum scores representing higher self-control. The internal consistency was sufficient for the present study (Iranian: Cronbach's α = .83; German: Cronbach's α = .81) and in line with the previous studies (e.g., Rauch et al., 2014).

Parenting behavior: Parenting behavior was assessed using the Alabama Parenting Questionnaire-Preschool Revision (APQ-PR; Clerkin, Halperin, Marks, & Policaro, 2007) answered by the parents. The German translation (Reichle, & Franiek, 2009) of the original version (APQ; Frick, 1991) was adapted for the preschool children and used in Germany. The English version of the APQ-PR was translated into Farsi and used in Iran. The APQ-PR includes three subscales: positive parenting (e.g., "You let your child know when he/she is doing a good job with something."), inconsistent parenting (e.g., "The punishment you give your child depends on your mood."), and punitive parenting (e.g., "You spank your child with your hand.") to measure different aspects of positive and negative parenting behaviors such as parental warmth and discipline. The response format was a 5-point Likert-scale ranging from 1 (*never*) to 5 (*always*). The total score was calculated separately for each subscale. The internal consistency of the items within each subscale (Iranian: Positive Parenting Cronbach's α = .82, Inconsistent Parenting Cronbach's α = .64, Punitive Parenting Cronbach's α = .64; German: Positive Parenting Cronbach's α = .74, Inconsistent Parenting Cronbach's α = .70. Punitive Parenting Cronbach's α = .80) was in line with the previously reported findings in the State of Qatar (e.g., Badahdah & Le, 2016) and Germany (e.g., Reichle & Franiek, 2009).

Household chaos: The level of household chaos was measured using the Confusion, Hubbub, And Order Scale (CHAOS; Matheny, Wachs, Ludwig, & Phillips, 1995) translated to German (Wirth et al., 2017) and Farsi. The CHAOS contains 15 items (e.g., "There is very little commotion in our home.") being reported by the parents. Of the 15 items, 7 indicate organization

while the remaining 8 items represent disorganization and are reverse-coded. Each item was rated on a 4-point Likert-type scale ranging from 1 (*very much like your own home*) to 4 (*do not like your own home*). The final score was the sum of all items with a higher score indicating more chaotic and less organized characteristics of the home. In the present study, the internal consistency was sufficient (Iranian: Cronbach's α = .88; German: Cronbach's α = .80).

Demographic variables: Demographics of children (gender, age, nationality, citizenship, number of siblings, mother tongue, and language spoken at home) and their families (highest educational degree of parents and their employment status) were reported by the parents.

Procedure

Recruitment took place via contacting kindergartens in both countries and sending out E-mails to the students and staff of the University of Tübingen in Germany. Parents gave a written informed consent before participating in the study and filling out the questionnaires. Moreover, parents signed an additional consent form for the video recording during the delay of gratification task. All children received a small present for their participation. The study was approved by the ethics committee of the Tehran University of Medical Sciences in Iran and the local ethics committee of the University of Tübingen in Germany.

The delay of gratification task took place in the kindergartens in Iran and either in kindergartens or in the laboratory of the Department of School Psychology at the University of Tübingen in Germany. Different testing environment (laboratory vs. kindergarten) in Germany did not predict children's performance in the delay of gratification task (p = 1.00, *Fisher's exact test*). The experimenters attempted to remove or cover all distracting or entertaining things in the room before testing the children. Each child was tested individually in one session of at most 45 min. The trained experimenters were female undergraduate students of the University and gave instructions to the children in their local language, which was Farsi in Iran and German in Germany.

Furthermore, English versions of all questionnaires were translated into Farsi by two bilingual PhD students from the Psychology field and one bilingual PhD student from outside the field using a well-established method of forward- and backward-translations, following the guidelines of the World Health Organization (WHO, n.d.).

Rating the behavioral strategies

The waiting times starting from the moment the experimenter left the room and ending with her return, were selected. Then, videos of the waiting times were cut into one-min clips. Thus, the one-min clips showing the child during the waiting time were included and the video clips showing interactions with the experimenter were excluded. Moreover, video clips shorter than one min as well as last clips were also excluded. The sequence of all one-min clips was randomized but fixed for all raters.

All items of the rating scale were rated as events that "occurred" or "did not occur" during that one minute video. All video clips of the Iranian children were rated by a German Master student of School Psychology and 70% of the video clips were additionallyrated by an Iranian PhD student of School Psychology to establish the inter-rater reliability (IRR). All video clips of the German children were rated by an Iranian PhD student of School Psychology and 94% of the video clips were additionally rated by two German undergraduate Psychology students. The verbal domain was excluded from the ratings due to the lack of enough raters to calculate IRR for the Farsi-speaking children. The video clips were played with a standard media player and headphones. All raters received the written descriptions as well as video examples of all rating items. An 'occurred' and a 'did not occur' video examples were presented for each rating item. Subsequently, a practice rating session was conducted and inter-rater discrepancies were resolved. The child's average score of each item over all one-min clips were calculated and aggregated for each domain. The IRR was assessed by intra-class-correlation coefficient (ICC; Hallgreen, 2012; Shrout & Fleiss, 1979). The ICC was calculated using the statistical software of SPSS (version 2017). The "model", "type" and "unit" can be specified for this analysis. The "model" was set to "mixed", because all video clips were not rated by all raters. The "type" was set to "absolute agreement" instead of consistency in rank-order. The "unit" set to "single" reflected the reliability of the ratings of a random rater who received the same trainings as the raters in the present study. Acceptable ICC values range between .60 and 1.00 (Hallgreen, 2012) with higher ICC values indicating better IRR. Results of ICC for the present study are listed in Table 1, representing excellent IRR.

Table 1.
Intra-Class Correlation Coefficient of the Behavioral Strategies

Strategy	Iranian (n = 37)	German (n = 29)
Focusing	.98	.98
Withholding	.89	.97
Distracting	.99	.97

Note. ICC_{single} – intra-class correlation coefficient for the mean values of the two raters for the Iranian sample and three raters for the German sample.

Analysis

Generally, children who chose two chocolate bars and participated in the delay of gratification task (Iranians: 61; Germans: 29; see Table 1) were included in the analyses. The performance in the delay of gratification task was operationalized as a categorical variable (waited 25 min vs. did not wait 25 min). Conclusions on factors that increase or decrease the probability of waiting 25 min seemed more meaningful because of the high number of German children who waited 25 min in the delay of gratification task. However, all children who did not wait 25 min in the delay of gratification task, despite their different waiting times, were grouped in one category (i.e., did not wait 25 min) and the investigation of factors that enhance or decrease the probability of waiting was limited due to this restricted variance. Therefore, to cover all the waiting times, a linear regression analyses was performed to test the relationships between the waiting time as the continuous outcome variable and study measures as the predictors separately for Iranian and German children who did not wait 25 min in the delay of gratification task. The results of the linear regression analyses revealed no significant relationships between the study measures and the waiting time in Iranian children. However, the results showed that self-control and household chaos have a positive relationship with waiting time in German children who could not manage to wait 25 min in the delay of gratification task (see Appendix B).

Separate logistic regression analyses were conducted to test the relationship between the performance in the delay of gratification task (waited 25 min vs. did not wait 25 min) as the categorical outcome variable and each predictor: self-control, parenting behaviors (i.e., positive parenting, negative parenting, inconsistent parenting), and household chaos. Moreover, nationality and the interaction of nationality and each predictor (e.g., nationality × self-control)

were also included as predictors in each regression model to compare the above-mentioned relationships between Iranian and German children. The predictors were added to the model hierarchically in different orders to build the simplest model, including only the predictors, which improved the model significantly (Field, 2013). Furthermore, separate logistic regression analyses were calculated to investigate the relationship between the performance in the delay of gratification task (did not wait 25 min vs. waited 25 min) as the categorical outcome variable and each behavioral strategy (i.e., Focusing, Withholding, Distracting), nationality and the interaction of nationality and each behavioral strategy (e.g., nationality × Focusing) as the predictors. The scale for the video-rated predictors ranged from 0 (occurred) to 1 (not occurred). Simple slope analysis (Aiken & West, 1991) was used to further investigate the nature of the significant interaction effects. The level of significance was set to $\alpha < .05$ for all analyses.

3.3.2 Results

Descriptive and Test Statistics

Descriptive and test statistics for the demographic variables and study measures in Iranian and German children are presented in Table 2. In case of non-normally distributed variables, Mann-Whitney-U tests and for normally distributed variables *t*-tests were used. Fisher's exact test was used for the categorical variables. The results revealed that Iranian and German children who participated in the delay of gratification task did not differ in most of the demographic variables including age, gender, parents' educational level, and parent's employment status. However, Iranian children had significantly less siblings, $U = 1156.50$, $p = .011$, and kindergarten attendance, $U = 1553.50$, $p < .001$, than German children. In addition, performance in the delay of gratification task was not predicted by gender or kindergarten attendance (see Appendix C). Furthermore, Iranian and German children did not differ in parents-reported self-control, $t(57.76) = 1.94$, $p = .057$. However, positive parenting, $U = 513.50$, $p = .001$, inconsistent parenting, $t(71.86) = 5.39$, $p < .001$, punitive parenting, $U = 569.50$, $p = .006$, and household chaos, $t(67.32) = 2.40$, $p = .019$, were rated significantly higher by Iranian parents than German parents.

Table 2.
Descriptive and Test Statistics of Demographic Variables and Study Measurements

Variable	Iranian[a] (n = 61)	German[a] (n = 29)	Diff P
Age in years (*SD*)	4.90 (0.45)	5.02 (0.47)	.072[b]
Gender, female (%)	44	55	.373[c]
Number of siblings (*SD*)	0.70 (0.88)	1.07 (0.70)	**.011**[b]
Parents' educational level			
Mother, ≤ 10 years of school (%)	18	21	.779[c]
Father, ≤ 10 years of school (%)	15	28	.161[c]
Parents' employment status			
Mother, unemployed (%)	33	24	.468[c]
Father, unemployed (%)	10	3	.421[c]
Kindergarten attendance in month (*SD*)	17.75 (6.46)	34.03 (12.28)	**<.001**[b]
Performance in the delay of gratification task			
Waited 25 min (%)	10	59	**<.001**[c]
Waiting time in min (*SD*)	6.90 (7.73)	19.31 (7.68)	**<.001**[b]
Behavioral strategies			
Focusing (*SD*)	.20 (0.14)	.14 (0.09)	.093[b]
Withholding (*SD*)	.12 (0.10)	.19 (0.07)	**.006**[b]
Distracting (*SD*)	.16 (0.07)	.19 (0.07)	.089[b]
Self-control (*SD*)	46.07 (8.80)	42.34 (8.35)	.057[d]
Parenting behavior			
Positive parenting (*SD*)	49.61 (6.51)	46.45 (3.64)	**.001**[b]
Inconsistent parenting (*SD*)	19.07 (4.17)	14.83 (3.11)	**<.001**[d]
Punitive parenting (*SD*)	10.26 (3.45)	8.38 (3.11)	**.006**[b]
Household chaos (*SD*)	27.98 (5.66)	25.31 (4.55)	**.019**[d]

Note. [a]Children who chose two chocolate bars in the delay of gratification task. [b]Mann-Whitney-U test, [c]Fisher's exact test, [d]*t*-test. Bold *p*-values depict $p < .05$.

Statistical hypotheses testing

About 27% of the Iranian and German children who participated in the study chose only one chocolate bar and did, thus, not partake in the delay of gratification task. Among those Iranian children who chose two chocolate bars in the delay of gratification task (n = 61), about 10% waited 25 min, while the rest showed rule-breaking behaviors. Among the German children who chose two chocolate bars in the delay of gratification task (n = 29), about 59% waited 25 min, whereas the rest showed rule-breaking behaviors. Accordingly, significantly less Iranian children than German children waited 25 min in the delay of gratification task, $p < .001$, *Fisher's exact test*. As a result, waiting time in the delay of gratification task was significantly shorter in Iranian children than their German peers, $U = 1517.00$, $p < .001$, (see Table 2).

Furthermore, the results showed that the amount focusing strategies, $U = 380.00$, $p = .093$, and distracting strategies, $U = 629.50$, $p = .089$, during the waiting time did not significantly differ between Iranian and German children. However, Iranian children used significantly less withholding strategies than their German peers during the waiting time in the delay of gratification task, $U = 708.00$, $p = .006$, (see Table 2).

Control Questions

Control questions consisted of two questions: (1) Can you tell me what you have been waiting for? (2) How much do you like the chocolate bars? Chocolate bar was mentioned by 42% of Iranian children and 65% of German children in answer to the first control question. In response to the second control question, “not at all” was not chosen by any children and “very much” was reported by more than half of the Iranian (77%) and German (86%) children. There were no significant differences between Iranian and German children in their answers to the first, $p = .070$, Fisher's exact test, and second, $p = .404$, Fisher's exact test, control questions.

Furthermore, last meal time before the delay of gratification task was reported on average 98.93 min (SD = 41.25) for Iranian children and on average 94.31 min (SD = 44.50) for German children. There was no significant difference between the Iranian and German children in their last meal time, $U = 816$, $p = .452$. Neither the answers to control questions, nor the last meal time predicted the performance in the delay of gratification task (see Appendix D).

Relationship between performance in the delay of gratification task and behavioral strategies

A logistic regression analysis was performed with performance in the delay of gratification task (0 – *did not wait 25 min; 1 – waited 25 min*) as the outcome variable and nationality (0 – *Iranian*; 1 – *German*), focusing strategy, withholding strategy, distracting strategy, nationality × focusing strategy, nationality × withholding strategy, and nationality × distracting strategy interactions as the predictors. The predictors were entered into the model in separate steps with different orders and the ones that did not significantly improve the model were systematically removed from the model (see Appendix E). The result of the final logistic regression model is depicted in Table 3. The result shows the significant effect of nationality × focusing strategy interaction on the odds of waiting 25 min in the delay of gratification task, indicating that the relationship between focusing strategy and the odds of waiting 25 min differs between Iranian and German children.

Simple slope analysis, as shown in Table 4 and Figure 1, indicated a positive non-significant relationship between focusing strategy and the probability of waiting 25 min in the delay of gratification task in Iranian children. However, the coefficient of the simple slope in German children reflected a significant decreasing trend, thus, the more focusing strategies were used, the lower the probability of waiting 25 min in the delay of gratification task (see Figure 1).

Table 3.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Delay of Gratification Task in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-2.33	0.97	-2.40	**.016**	0.10
Nationality	4.88	1.44	3.38	**.001**	131.91
Focusing	2.46	3.55	0.69	.488	11.73
Nationality × Focusing	-18.59	8.19	-2.27	**.023**	8.44e-9

Note. R^2 = .30 (Cox & Snell) .41 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 12.06$, $p = .148$. Model $\chi^2(3) = 22.14$, $p < .001$.
β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Table 4.

Simple Slope Analysis of Focusing Strategy and the Probability of Waiting 25 min in the Delay of Gratification Task in Iranian and German Children

	b	*SE(B)*	*t*	*p*
Focusing in Iranians[a]	2.46	3.55	0.69	.488
Focusing in Germans[b]	-16.13	7.40	-2.18	**.029**

Note. [a]*n* = 35, [b]*n* = 28.

Bold *p*-values depict $p < .05$.

Figure 1.

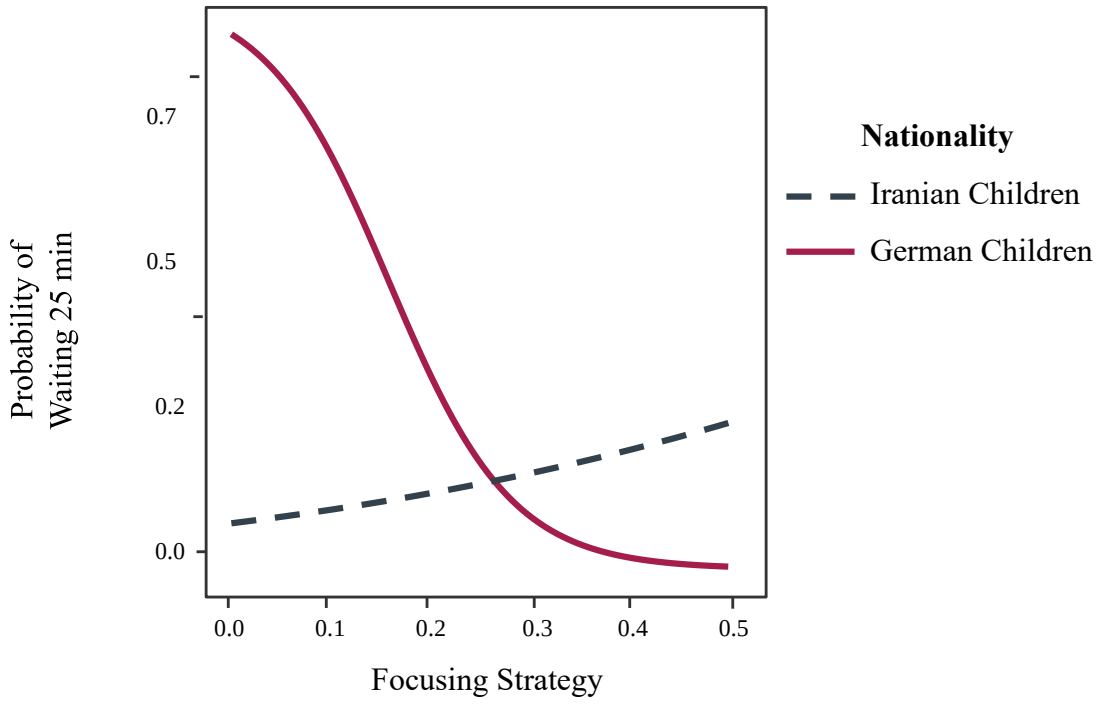

Figure 1. Simple slopes of the regression of the probability of waiting 25 min performance in the delay of gratification task on focusing strategy in Iranian and German children.

Relationship between performance in the delay of gratification task and self-control

A logistic regression analysis was performed with performance in the delay of gratification task (0 – did not wait 25 min; 1 – waited 25 min) as the outcome variable and nationality (0 – Iranian; 1 – German), self-control, and nationality × self-control interaction as the predictors which were entered into the model in separate steps. The result of the final logistic regression model is depicted in Table 5. The result revealed the significant effect of nationality × self-control interaction on the odds of waiting 25 min in the delay of gratification task, indicating that the relationship between self-control and the odds of waiting 25 min differs between Iranian and German children.

Simple slope analysis, as shown in Table 6, showed a non-significant positive relationship between self-control and the probability of waiting 25 min in the delay of gratification task in Iranian children. However, the coefficient of the simple slope in German children demonstrated a non-significant negative relationship between self-control and the probability of waiting 25 min in the delay of gratification task.

Table 5.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Delay of Gratification Task in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-9.17	3.90	-2.35	**.019**	1.04e-4
Nationality	11.00	4.43	2.48	**.013**	5.99e4
Self-control	0.14	0.07	1.90	.058	1.15
Nationality × Self-control	-0.17	0.09	-1.89	**.048**	0.84

Note. R^2 = .28 (Cox & Snell) .41 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 2.55$, $p = .959$. Model $\chi^2(3) = 29.34$, $p < .001$.
β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Table 6.

Simple Slope Analysis of Self-Control and the Probability of Waiting 25 min in the Delay of Gratification Task in Iranian and German Children

	β	$SE(\beta)$	t	p
Self-control in Iranians[a]	0.14	0.07	1.90	.058
Self-control in Germans[b]	-0.03	0.05	-0.72	.471

Note. [a]$n = 61$, [b]$n = 29$.

Relationship between performance in the delay of gratification task and parenting behavior

A logistic regression analysis was performed with performance in the delay of gratification task (0 – did not wait 25 min; 1 – waited 25 min) as the outcome variable and nationality (0 – Iranian; 1 – German), positive parenting, inconsistent parenting, punitive parenting, nationality × positive parenting, nationality × inconsistent parenting, and nationality × punitive parenting interactions as the predictors. The predictors were entered into the model in separate steps with different orders and the ones that did not significantly improve the model were removed (Appendix F). The result of the final logistic regression model is depicted in Table 7. The result showed the significant negative effect of inconsistent parenting on the odds of waiting 25 min in the delay of gratification task in Iranian children and German children (see Table 7).

Table 7.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Delay of Gratification Task in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	2.01	1.57	1.28	.201	7.46
Nationality	1.93	0.61	3.16	**.002**	6.91
Inconsistent parenting	-0.24	0.09	-2.67	**.010**	0.79

Note. $R^2 = .30$ (Cox & Snell) .43 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 5.91$, $p = .657$. Model $\chi^2(2) = 31.22$, $p < .001$. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables. Bold p-values depict $p < .05$.

Relationship between performance in the delay of gratification task and household chaos

A logistic regression analysis was performed with performance in the delay of gratification task (0 – did not wait 25 min; 1 – waited 25 min) as the outcome variable and nationality (0 – Iranian; 1 – German), household chaos, and nationality × household chaos interaction as the predictors which were entered into the model in separate steps. The result of the final logistic regression model is depicted in Appendix G and revealed no significant effect of the predictors on the odds of waiting 25 min in the delay of gratification task.

3.3.3 Discussion

The present study compared the performance and behavioral strategies in the delay of gratification task between Iranian and German preschool children. The hypothesis of the present study was that performance and strategies of Iranian and German children differed in the delay of gratification task. The results supported our hypotheses in that Iranian and German children differed in their performances and behavioral strategies: Iranian children waited less than German children in the delay of gratification task and in fact, the majority of German children waited the full 25 min without showing any rule-breaking behaviors until the experimenter returned to the room. Moreover, Iranian children used fewer withholding strategies than their German peers and focusing strategies undermined the probability of waiting 25 min in German but not Iranian children.

Altogether, our results showed that Iranian and German children differed in their performances in the delay of gratification task, suggesting that self-regulation abilities of children might vary across different contexts. This is consistent with previous studies, revealing that self-regulation abilities of children may be developed and applied differently in interdependent and independent countries (e.g., Chasiotis et al., 2006; Keller et al., 2004; Trommsdorff, 2009). However, in contrast to our findings, previous studies mainly found that children from interdependent countries outperformed their peers from independent countries on self-regulation tasks (e.g., Chasiotis et al., 2006; Keller et al, 2004; Lamm et al., 2018; Sabbagh et al., 2006). One reason might be due to the heterogeneity of the definition of self-regulation and the different ways to assess it in previous research. For instance, in a cross-cultural study on Cameroonian and German children, self-regulation was defined as children's obedience and, accordingly, assessed by asking children to comply with adults' requests (Keller et al., 2004). Thus, Cameroonian children who grew up in an interdependent context performed better than

their German peers form an independent context. In another example, self-regulation was measured by the snack delay task in which, similar to the delay of gratification task, children had to wait for the delayed snack/reward. However, unlike our delay of gratification task, waiting for the snack/reward was not self-imposed and the experimenter was present during the whole task (Chasiotis et al., 2006). The authors reported that Cameroonian children outperformed their German and Costa Rican peers on the snack delay task. In fact, children from interdependent contexts might perform better than children from independent contexts in self-regulation tasks assessing children's compliance or involuntary waiting, because parents frequently reinforce the social responsibility including obedience and respect towards elders. However, when the delay of gratification is self-imposed, as in the delay of gratification task, children from interdependent or independent contexts might behave differently in the absence of external control. The absence of external control is rather unusual for children in interdependent contexts and more common for children in independent contexts, so the latter might have an advantage in such a situation.

In contrast to this consideration, results of the only cross-cultural study that used the classical delay of gratification task to assess self-regulation indicated that Cameroonian children resisted the temptation better than German children (Lamm et al., 2018). This might be explained by the fact that Cameroonian children in their study were recruited from subsistence farmer families living in the rural areas, while Iranian children were recruited from industrial metropolitan regions. This might influence self-regulation abilities of children as it has been shown that even within one country, the level of interdependency is substantially higher in rural areas than urban regions (e.g., Freeman, 1997; Kashima et al., 2004). Furthermore, postponing gratification might not be always a wise choice, particularly in an unstable economic situation as in Iran during the past years accompanied by uncontrolled inflation and bank failures (International Monetary Fund, 2019), which might have had implications on how parents raised their children.

Our results also showed that Iranian children used fewer withholding strategies than their German peers to actively stop themselves from touching the reward. This might be because distracting strategies, in general, were used more by German children as they, consistent with their independent context, tried to adapt the environment to their individual goals by manipulating the situation (e.g., Lamm et al., 2018). Moreover, in line with previous studies in Western countries, the reward-oriented focusing strategies hampered performance in the delay of

gratification task in German children. Behavioral strategies, however, did not predict performance of Iranian children in the delay of gratification task, suggesting that the behavioral rating scales based on the reward-oriented and distracting categorization used by previous studies in Western countries might not be sufficient for detecting the relationships between self-regulatory strategies and children's performances in Eastern/Middle Eastern countries.

In addition, in the present study, inconsistent parenting characterized by unstable discipline, predicted the probability of waiting 25 min in the delay of gratification task in both Iranian and German children. The negative association between inconsistent parenting and performance in the delay of gratification task in Iranian and German children is in accordance with previous studies showing that reliability of the environment can influence children's performance in the delay of gratification task. There is evidence that unreliable environments in which children cannot trust adults, undermine children's performance in the delay of gratification task (Kidd, Palmeri, & Aslin, 2013). In the same vein, inconsistent parenting might influence performance of children in the delay of gratification task through its negative impacts on the reliability of the environment.

Limitations of the study and future perspective

Although cultural context and country are not identical (Rogoff, 2003), the nationality/country representing participants' shared national identity, was used as a proxy for cultural context in this study. In addition, in the present study, Iran was considered an interdependent context (Hofstede, 1984) and Germany represented an independent context in accordance with the literature (Hofstede, 1984; Keller & Kärtner, 2013; Tõugu, Tulviste, Kasearu, Talves, & Albert, 2018). So, while our distinction is well situated in the available literature, there is a lack of recent studies, especially concerning Iran. Due to this lack of adequate recent studies, previous consideration Iran as an interdependent context may no longer not warranted, because the society might have changed in the last 35 years, especially in the urban contexts, in which we recruited our children. Because of the lack of studies, we cannot say that this is the case, but it is a caveat and a limitation, which in our view deserves more attention especially as regards rapidly developing societies.

Another limitation of this study was the construct validity of the parent-reports as they were designed and validated for Western countries. For instance, self-control as well as household chaos, which were rated higher by Iranian parents, unexpectedly did not predict the

children's performance in the delay of gratification task. This might be due to limited validity of these measures in cross-cultural research, because parents of one culture might compare themselves or their children to different references than those in another culture (Heine, Lehman, Peng, & Greenholtz, 2002).

3.3.4 Conclusion

In conclusion, our results show that Iranian children waited less and used fewer withholding strategies than their German peers in the delay of gratification task. Moreover, focusing strategies undermined the performance in the delay of gratification task in German but not in Iranian children. Accordingly, our findings suggested that previously discovered differences in the self-regulation abilities of children in interdependent and independent contexts might be valid, however, which group shows greater self-regulation abilities might depend on specific contexts where children grew up.

In sum, we have observed differences between an independent and an interdependent culture in the delay of gratification performance, however, in the opposite direction as reported in the literature. The reasons for these diverging findings could lie in sampling within the country (rural vs. urban), type of self-regulation measure and paradigm, a rapidly changing society or other unknown variables. We believe that investigations of the role of cultural context in delay of gratifications need to consider different countries, because they might differ in other variables than their independency or interdependency as well. Only with such a multi-national approach, we can find out, which interaction between nationality and the afore-mentioned variables drives major self-regulation differences already in very young children.

Appendix A

Adapted Rating Scale[a] for Rating the Behavioral Strategies Used by Children in the Marshmallow Test

Domain	Strategies	Item
Visual	Focusing	Looks towards the reward
	Withholding	Eyes are closed
	Distracting	Looks upwards
		Looks at its own hands
Motor	Focusing	Touching the reward
		Almost touching the reward
		Reaching or pointing towards the reward
		Hands are (relaxed) above the table
	Withholding	Hands are placed on top of one another
		Holding own hands
		Hands are underneath the table
	Distracting	Head rests on the hand(s)
		Touches own face or mouth
		Fine motor movements (e.g., fiddles with clothes)
		Touches/holds extern (not task- related) object
	Focusing	Faces the reward directly
		Faces the reward closely, within a 45° angle
	Distracting	Face is left side
		Face is right side
		Face is directed upwards
		Face is directed downwards
		Face is directed opposite of the reward
		Head is resting on the table
	Focusing	Body is turned towards the reward
	Distracting	Body is turned sideways
		Body is turned completely around
		Rocks or dances with its body

Note. [a]Developed by Ravenswaaij and colleagues (in press) and adapted for the present study.

Appendix B

Linear Model of Predictors of Waiting Time in the Marshmallow Test in Iranian Children

Table B.1.

Linear Model of Predictors of Waiting Time in the Marshmallow Test in Iranian Children

Predictor	*b*	*SE(B)*	Standardized *b*	*t*	*p*
Constant	-1.79	12.30		-0.15	.885
Self-control	0.08	0.10	0.13	0.79	.433
Kindergarten attendance	-0.08	0.11	-0.10	-0.69	.495
Positive parenting	0.08	0.14	0.11	0.56	.579
Inconsistent parenting	0.04	0.21	0.03	0.19	.849
Punitive parenting	-0.38	0.28	-0.26	-1.36	.182
Haushold chaos	0.13	0.19	0.15	0.69	.493

Note. $n = 55$.
$R^2 = .11$, $F(6, 54) = 1.04$, $p = .411$.

Table B.2.

Linear Model of Predictors of Waiting Time in the Marshmallow Test in German Children

Predictor	*b*	*SE(B)*	Standardized *b*	*t*	*p*
Constant	-38.65	30.68		-1.26	.263
Self-control	0.48	0.18	0.88	2.69	**.043**
Kindergarten attendance	0.17	0.13	0.36	1.29	.254
Positive parenting	0.09	0.66	0.04	0.13	.898
Inconsistent parenting	-0.08	0.42	-0.05	-0.20	.848
Punitive parenting	-0.02	0.31	-0.02	-0.06	.951
Haushold chaos	0.81	0.29	0.86	2.81	**.037**

Note. $n = 12$.
$R^2 = .72$, $F(6, 11) = 2.17$, $p = .207$.
Bold *p*-values depict $p < .05$.

Appendix C

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min from Gender and Kindergarten Attendance

Table C.1.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-2.33	0.60	-3.88	**< .001**	0.10
Nationality	2.49	0.82	3.04	**.002**	12.06
Gender	0.27	0.86	0.31	.766	1.29
Nationality × Gender	0.10	1.15	0.09	.930	1.11

Note. R^2 = .23 (Cox & Snell) .34 (Nagelkerke). Model $\chi^2(3) = 24.06$, $p < .001$.
Outcome variable performance in the Marshmallow Test was coded as 1 – waited 25 min; 0 – did not wait 25 min. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Table C.2.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-1.33	1.30	-1.02	.300	0.26
Nationality	2.56	1.74	1.47	.137	13.30
Kindergarten attendance	-0.05	0.07	-0.71	.482	0.95
Nationality × Kindergarten attendance	0.03	0.08	0.38	.750	1.03

Note. R^2 = .24 (Cox & Snell) .36 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 7.48$, p =.486. Model $\chi^2(3) = 24.98$, $p < .001$.
Outcome variable performance in the Marshmallow Test was coded as 1 – Waited 25 min; 0 – did not wait 25 min. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Appendix D

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test from the Control Questions

Table D.1.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test in Iranian and German Children

Predictor	β	$SE(\beta)$	*z*-Statistic	*p*	e^{β}
Constant	-2.80	0.73	-3.84	**< .001**	0.06
Nationality	2.40	0.97	2.47	**.014**	11.00
First control question	1.10	0.91	1.21	.227	3.00
Nationality × First control question	0.08	1.22	0.07	.948	1.08

Note. R^2 = .26 (Cox & Snell) .40 (Nagelkerke). Model $\chi^2(3) = 27.49$, $p < .001$.
β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.

Table D.2.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test in Iranian and German Children

Predictor	β	$SE(\beta)$	*z*-Statistic	*p*	e^{β}
Constant	-0.92	0.59	-1.56	.121	0.40
Nationality	0.92	1.16	0.79	.430	2.50
Second control question	-2.20	0.93	-2.37	**.019**	0.11
Nationality × Second control question	2.60	1.43	1.82	.068	13.50

Note. R^2 = .28 (Cox & Snell) .41 (Nagelkerke). Model $\chi^2(3) = 29.81$, $p < .001$.
β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold *p*-values depict $p < .05$.

Table D.3.

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-1.25	1.13	-1.11	.266	0.29
Nationality	2.08	1.45	1.43	.151	8.03
Last meal time	-0.01	0.01	-1.00	.388	0.99
Nationality × Last meal time	0.00	0.01	0.00	.718	1.00

Note. R^2 = .24 (Cox & Snell) .36 (Nagelkerke). Model $\chi^2(3) = 24.93$, $p < .001$.
β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold *p*-values depict $p < .05$.

Appendix E

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test from the Behavioral Strategies in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-2.50	1.50	-1.67	.096	0.08
Nationality	2.36	3.15	0.75	.453	10.64
Focusing	3.03	3.96	0.77	.444	20.68
Withholding	-3.40	5.16	-0.66	.511	0.03
Distracting	2.48	7.43	0.33	.738	11.95
Nationality × Focusing	-20.90	9.83	-2.13	**.034**	8.38e-10
Nationality × Withholding	7.98	10.60	0.75	.451	2.91e3
Nationality × Distracting	8.71	10.97	0.79	.427	6.09e3

Note. R^2 = .33 (Cox & Snell) .45 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 6.49$, $p = .592$. Model $\chi^2(7) = 24.98$, $p = .001$.
Outcome variable performance in the Marshmallow Test was coded as 1 – Waited 25 min; 0 – did not wait 25 min. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Appendix F

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test from Parenting Behaviors in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	6.38	5.98	1.07	.286	5.91e2
Nationality	-9.52	8.57	-1.11	.266	7.3e-5
Positive parenting	-0.70	0.09	-7.78	.423	0.93
Inconsistent parenting	-0.13	0.14	-0.93	.346	0.88
Punitive parenting	-0.30	0.26	-1.15	.246	0.74
Nationality × Positive parenting	0.27	0.16	1.69	.096	1.31
Nationality × Inconsistent parenting	-0.20	0.22	-0.91	.370	0.82
Nationality × Punitive parenting	0.20	0.30	0.67	.514	1.22

Note. R^2 = .33 (Cox & Snell) .49 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(8) = 3.98$, $p = .856$. Model $\chi^2(7) = 36.27$, $p < .001$.
Outcome variable performance in the Marshmallow Test was coded as 1 – Waited 25 min; 0 – did not wait 25 min. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

Appendix G

Results of the Logistic Regression Analysis Predicting the Odds of Waiting 25 min in the Marshmallow Test from Household Chaos in Iranian and German Children

Predictor	β	$SE(\beta)$	z-Statistic	p	e^{β}
Constant	-0.35	2.21	-0.16	.875	0.71
Nationality	0.57	3.09	0.18	.855	1.76
Household chaos	-0.07	0.08	-0.88	.407	0.93
Nationality × Household chaos	0.07	0.19	0.37	.534	1.08

Note. R^2 = .24 (Cox & Snell) .35 (Nagelkerke). Hosmer and Lemeshow goodness of fit $\chi^2(7) = 8.31$, $p = .306$. Model $\chi^2(3) = 24.10$, $p < .001$.
Outcome variable performance in the Marshmallow Test was coded as 1 – Waited 25 min; 0 – did not wait 25 min. β – regression coefficient (ln terms of the log-odds ratios); $SE(\beta)$ standard error of the regression coefficient; e^{β} – odds ratio of the predictor variables.
Bold p-values depict $p < .05$.

4. GENERAL DISCUSSION

The present dissertation aims to contribute to the better understanding of the context-sensitivity of self-regulation and its association with academic performance. With the aim to contribute to this goal, *Study 1* first investigated the relationship between self-regulation and mathematics performance in young adults. *Study 2* then examined this relationship in young adults in Germany and Iran. Lastly, *Study 3* investigated the self-regulation abilities of German and Iranian preschool children.

In this chapter, the central empirical findings of the three studies incorporated in the present dissertation are summarized and discussed. Furthermore, how these findings address the research questions raised in Chapter 2 and contribute to the main goal of the present dissertation will be discussed. Subsequently, implications of the results for research and practice and the limitations of the present dissertation from a methodological point of view are discussed. Then, this chapter provides an outlook for open research questions and recommendations for future research. Finally, the discussion places the overall results of the present dissertation and provides suggestions for future cross-cultural/national studies.

4.1 Summary and Discussion of the Studies' Main Results

Study 1 investigated the relationship between different aspects of self-regulation and mathematics performance in young adults. In this study, different aspects of self-regulation including behavioral self-regulation and self-control were assessed by self-reports and several cognitive aspects (i.e., WM and planning) were measured by computerized tasks. Mathematics performance was measured by a computerized complex multiplication task. In total, 40 undergraduate German students aged between 19 and 21, of whom 33 were female, were tested in this study.

The findings of *Study 1* showed that behavioral self-regulation measured by ADHD rating scales, unexpectedly, did not predict mathematics performance but self-control and planning measured by self-reports and computerized task respectively, had a significant positive relationship with the mathematics performance of college students. One possible reason that behavioral self-regulation did not predict mathematics performance is that the principle purpose

of the self-regulation measure used in this study is for the assessment of ADHD symptoms. ADHD symptoms might reflect specific difficulties that do not play a role for healthy young adults. Moreover, despite the association between ADHD symptoms and self-regulation deficits in individuals with ADHD (Barkley, 1997), this association might not be valid for healthy adults like those of our sample who displayed limited variance in ADHD symptoms. However, the results revealed the positive significant relationship between self-control as an aspect of self-regulation and mathematics performance. This suggests that college students with greater self-control abilities might be better able to concentrate on a task and suppress unwanted thoughts, hence they responded faster in solving the mathematics problems. This finding is also consistent with previous studies demonstrating that individuals with self-control deficits, such as patients with frontal lobe dysfunctions, exhibit slower responses for a wide range of tasks (e.g., Dimoska et al., 2003; Kofler et al., 2013; Senderecka et al., 2012). Moreover, the results of our study showed that planning predicted mathematics performance and WM exerted its influence on mathematics performance indirectly via planning. This suggests that complex multiplication performance may not be predicted by WM per se, but rather by WM-related cognitive and behavioral factors such as planning and self-control.

Taken together, the main findings of *Study 1* were consistent with previous studies involving children (e.g., Bull et al., 2008; Bull & Lee, 2014; Clark et al., 2010; Von Aster & Shalev, 2007), suggesting a positive association between different aspects of self-regulation and mathematics performance. Therefore, the first research question raised in chapter 2 concerning whether different aspects of self-regulation predict mathematics performance in young adults, was addressed by *Study 1,* indicating that self-control and planning, predicted mathematics performance in college students.

Study 2 examined the relationship between self-regulation and mathematics performance in young adults in Germany and Iran. Self-regulation ability and mathematics performance of 44 Iranian undergraduate students were assessed and the results compared with those of *Study 1*, which examined the same relationship in German college students. The same measurement tools used in *Study 1* were also employed in this study to assess self-control as an aspect of self-regulation and mathematics performance. Moreover, the field of study of the students was also considered in this study, but only for Iranian students, since all the German participants were students of Human Sciences, whereas about half of the Iranian participants were studying Human

Sciences (i.e., less math-related fields) and the other half were students of Engineering/Informatics (i.e., more math-related fields).

The findings of this study showed that self-regulation predicted the mathematics performance only in German students and not in Iranian students. However, when the field of study was taken into account for Iranian students, self-regulation predicted mathematics performance in the subgroup of Iranian students studying Human Sciences. In addition, the results showed that Iranian students of Engineering/Informatics performed better than Iranian students of Human Sciences on the mathematics task. Therefore, it seems that the mathematics task was less difficult for the students of Engineering/Informatics as compared to the students of Human Sciences, hence, students of Engineering/Informatics might need less self-regulation to solve the mathematics problems. This is in line with the results of previous studies showing that self-regulation is most needed when facing challenging tasks, which rely on multiple cognitive processes (e.g., Kanfer & Ackerman, 1989; Steele-Johnson et al., 2000). In our case, a similar mathematics task seems to be more challenging for students of Human Sciences than it is for students of Engineering/Informatics. Students of Engineering/Informatics performed significantly better than students of Human Sciences in the mathematics task. Moreover, no difference was found concerning the effect of field of study on mathematics performance for Iranian students with high self-regulation in the present study, suggesting that individuals with high self-regulation can perform well independent of task difficulty as they do not need high self-regulation when facing challenging tasks.

Furthermore, the results indicated that the relationship between self-regulation and the mathematics performance of German students did not differ significantly from the whole Iranian group nor from Iranian students of Human Sciences. Altogether, the main findings showed that the relationship between self-regulation and mathematics performance is similar between German and Iranian college students when the field of study is considered. This is consistent with a cross-cultural study that examined the association between self-regulation and the performance of Chinese and North American children on simple and complex mathematical tasks (Lan et al., 2011). Interdependence-oriented context prevails in China, while independence-oriented context is dominant in North America, however, the authors reported that the relationship between cognitive aspects of self-regulation and performance on both simple and complex mathematical tasks are similar between Chinese and North American children.

Overall, our findings showed that independence-orientation and interdependence-orientation, which may exist in Germany and Iran to different degrees, might not significantly influence the positive relationship between self-regulation and mathematics performance in young adults. Accordingly, the second and third research questions raised in Chapter 2 concerning whether the relationship between self-regulation and mathematics performance differs between Germany and Iran, and whether the field of study affects this relationship, were both addressed by *Study 2*.

Study 3 investigated the self-regulation abilities of German and Iranian preschool children. Self-regulation ability was operationalized as performance and strategies used by children in a delay of gratification paradigm (Mischel, 1996). Thus, the behaviors of the children while performing a delay of gratification task were video recorded and later rated with respect to strategies that direct the attention towards a reward or away from it. Moreover, parenting behaviors were assessed by parent-reports to examine the relationship between parenting behavior and the self-regulation abilities of German and Iranian children.

The findings indicated that German children waited longer than their Iranian peers in the delay of gratification task and in fact, the majority of German children waited the whole 25 min and received the delayed larger reward. This finding is in accordance with the assumption that Germany and Iran, as described before, may provide two different contexts with distinct cultural characteristics, which may affect the self-regulation abilities of children. The results are also consistent with previous studies, indicating that the self-regulation abilities of children may be developed and applied differently in interdependence-oriented and independence-oriented countries (e.g., Chasiotis et al., 2006; Keller et al., 2004; Lamm et al., 2018). However, this finding is in contrast with previous studies demonstrating that children from interdependence-oriented countries outperformed their peers from independence-oriented countries on self-regulation tasks (e.g., Chasiotis et al., 2006; Keller et al, 2004; Lamm et al., 2018). One reason might be that self-regulation was defined and measured differently in previous research. When self-regulation was defined as obedience and measured by compliance (e.g., Keller et al., 2004) or involuntary waiting (e.g., Chasiotis et al., 2006), children from interdependence-oriented contexts might perform better than children from independence-oriented contexts as their parents frequently reinforce obedience and respect towards elders. However, when the delay of gratification is self-imposed, as with the task used in our study, children from interdependence-

oriented or independence-oriented contexts might behave differently in the absence of external control. The results of the only cross-cultural study using a similar self-regulation measure as our study showed that Cameroonian children resisted the temptation better than German children (Lamm et al., 2018). This might be due to the fact that the Cameroonian children in their study were recruited from farmer families living in the rural areas, while the Iranian children in our study were recruited from industrial metropolitan regions. It has been shown that even within a single country, the level of interdependency is substantially higher in rural areas than urban regions (e.g., Freeman, 1997; Kashima et al., 2004).

Our results also showed that German children used more withholding strategies than their Iranian peers to stop themselves from touching the reward, potentially because distracting strategies, in general, were used more by the German children. The German children, consistent with their independence-oriented context, tried to physically manipulate the situation to adapt it to their personal goals (e.g., Lamm et al., 2018). Furthermore, the focusing strategies hampered performance in the delay of gratification task with German children, which was in line with previous studies from Western countries (e.g., Eigsti et al., 2006; Manfra et al., 2014; Neuenschwander & Blair, 2017; Rodriguez et al., 1989). Surprisingly, these behavioral strategies did not predict the performance of the Iranian children in the delay of gratification task. This suggests that the reward-oriented and distracting strategies classification developed and used by previous studies in Western countries might not be valid for detecting the relationships between self-regulatory strategies and performance in preschool children from Eastern/Middle Eastern countries. Iranian preschool children might use different self-regulatory strategies to resist the temptation, hence, the relationship between motoric distracting strategies and waiting longer in the delay of gratification task in Iranian sample would be not significantly positive as in previous Western studies.

In addition, the results showed that inconsistent parenting predicted unsuccessful performance in the delay of gratification task for both Iranian and German children. This is in accordance with previous studies showing that unreliable environments in which children cannot trust adults, undermine performance in the delay of gratification task (Kidd et al., 2013). Accordingly, inconsistent parenting might have influenced the performance of German and Iranian children in our study in the delay of gratification task through its negative impacts on the reliability of the environment.

Altogether, the research questions of *Study 3* raised in chapter 2 were addressed by the above-mentioned results, showing that: a) German children performed better in a delay of gratification task than their Iranian peers, b) withholding strategies were used more by German children than their Iranian peers, c) focusing strategies had a negative association with performance in the delay of gratification task for German but not Iranian children, d) parenting behaviors (positive, inconsistent, punitive) differed between Iran and Germany e) only inconsistent parenting behavior predicted performance of German and Iranian children in the delay of gratification task.

In sum, the findings of the three studies incorporated in the present dissertation contribute to the overarching goal of the dissertation by providing empirical evidence for the context-sensitivity of the self-regulation at preschool age and comparing the association between self-regulation and mathematics performance in young adults. These findings suggest that self-regulation abilities might differ at preschool age between countries, however, their subsequent association with mathematics performance might be similar for young adults across countries.

4.2 Implications for Research and Practice

Implications for Research

The results of *Study 1* and *2* extend previous findings on the positive relationship between self-regulation and mathematics performance in children to young adults and suggest that this relationship might be similar for college students across countries when the field of study is considered. With regard to the confounding effect of field of study on the predictive validity of self-regulation, our results suggest that the previously discovered differences in the relationship between self-regulation and academic performance between countries might be due to the lack of control for the effect of field of study. Therefore, not only cross-cultural, but also within-culture research should consider the possible confounding effect of field of study when examining the relationship between self-regulation and mathematics performance in college students.

The findings of *Study 3* demonstrated differences with respect to self-regulation abilities in German and Iranian preschool children. However, the findings also showed that the direction of these differences vary from the results reported in the previous cross-cultural studies. Hence, the assumption discussed in the previous studies that children from interdependence-oriented contexts generally show a greater level of self-regulation ability than children from

independence-oriented contexts is to be viewed critically on the basis of our results. Moreover, finding these differences at preschool age give rise to the need for developmental research applying longitudinal designs to understand how independence-oriented and interdependent-oriented contexts can influence later association between self-regulation and academic performance.

Furthermore, to date, most of the research on self-regulation and its correlates has been developed by Western researchers working with WEIRD samples from Western industrialized countries such as North America (Henrich et al., 2010; Trommsdorff, 2009). The findings of the empirical studies incorporated in the present dissertation will help to improve researchers' knowledge about self-regulation processes in non-Western countries and populations. For instance, the results of *Study 3* improve the understanding of self-regulation abilities of children from a Middle Eastern country, which has so far been little studied cross-culturally. Studying self-regulation processes in Middle Eastern countries is important because, as described before, these countries share a unique cultural context, which makes them different from other Eastern countries such as East Asian countries, which actually have been the subject of cross-cultural studies. Therefore, finding differences in regard to the self-regulation abilities of preschool children might encourage future research in this region.

Implications for Practice

Various self-regulatory processes may exist with different strengths in independence-oriented and interdependence-oriented contexts, as has been shown in previous studies. However, this may not significantly influence their level of contribution to the mathematics performance of college students. Therefore, the findings of *Study 1* and *Study 2* about the important role of self-regulation in predicting mathematics performance apart from the effect of nationality can help education policymakers to develop policies to help improve academic performance of nationally diverse college students who struggle with inadequate self-regulation abilities.

Another important domain in which the knowledge gained from the present dissertation may be profitably applied includes educator-child interactions in kindergartens and preschools. The results of *Study 3* showing that self-regulatory strategies used by preschool children differed between Western and Middle Eastern countries, enhance the knowledge on the context-sensitivity of these strategies for the educators who aim to strengthen these strategies in children.

This may be particularly important for educators who are increasingly confronted with greater cultural diversity in their classes. For instance, in the case of children from Middle Eastern families who have immigrated to Germany, the effect of cultural context on the self-regulation abilities of children can be considered by the educators who aim for evaluating these skills.

Finally, employing a cross-cultural approach for investigating various aspects of self-regulation has practical relevance for developing measures that tap into self-regulation processes at the transcultural level. For instance, understanding the underlying processes of self-regulation abilities across various cultural contexts might appeal to researchers, educational policymakers, and teachers who want to develop test batteries that can evaluate more effectively these abilities in different countries.

4.3 Limitations

Conducting research across nations and cultures has several unique methodological challenges (for the review see Buil, de Chernatony, & Martínez, 2012). Accordingly, the present dissertation also comprises several methodological limitations that future studies should be aware of. The following section discusses these methodological limitations and the extent to which they can restrict the interpretation of the results of the present dissertation.

Sample and Setting

Due to the selective sample collection (e.g., recruitment only from Universities in *Study 2* or recruitment only from kindergartens in Iran in *Study 3*), the German and Iranian samples tested in the present dissertation are not representative of all German and Iranian young adults and preschool children. Moreover, neither Tehran is representative for Iran nor Tübingen is representative for Germany. The generalizability of the findings, therefore, is limited. Most likely correlations get higher in more representative samples because of more variance within the sample. Furthermore, in *Study 2*, all German participants were in the same field of study (i.e., Human Sciences), whereas approximately half of the Iranian participants were studying Human Sciences and the other half were students of Engineering/Informatics. Hence, the effect of field of study was only taken into account in the Iranian sample and could not be generalized to German or any other national group. Therefore, the results of *Study 2* should be carefully interpreted with respect to differentiating between the effect of context and the effect of field of study on the relationship between self-regulation and mathematics performance.

Measures

First of all, although cultural context and country are not identical (Rogoff, 2003), the nationality/country representing the shared national identity of the participants was used as a proxy for cultural context in the present dissertation. Therefore, cultural variables that may be related to self-regulation were not directly assessed and the present dissertation relied upon conjectures and previous literature regarding assumed cultural differences that could influence self-regulation. In addition, in the present dissertation, Iran was considered as an interdependence-oriented context in accordance with the literature (Hofstede, 1984) and Germany represented an independence-oriented context (Hofstede, 1984; Keller & Kärtner, 2013; Tõugu, et al., 2018). However, while this distinction is well situated in the available literature, there is a lack of recent studies concerning Iran. Due to the lack of adequate recent studies, the previous consideration of Iran as an interdependence-oriented context may no longer be warranted because the society might have changed in the last 35 years. So, it is a limitation which deserves more attention especially in regard to rapidly developing societies.

When conducting research across different cultures and/or countries, it is essential to establish comparability or equivalence at each stage of the research process. Measure equivalence is one of the most essential methodological issues to establish. Measure equivalence provides assurance that a measurement is comparable across countries and populations. One way to deal with this issue is to use different translation techniques, such as back-translation. In the back-translation technique, a bilingual translator translates a research measurement into another language and then, a second independent bilingual translator translates the measurement back into the original language. Discrepancies in the translations will be corrected until equivalence is achieved. The back-translation technique was adopted in the present dissertation for the translation of all the questionnaires from German or English into Farsi (i.e., official language of Iran). However, that may not be enough to reach measure equivalence since the measure includes the definition of the construct that it aims to assess. Hence, measure equivalence is strongly interrelated with construct equivalence. The lack of construct equivalence suggests that the construct may not have the same meaning in all cultures and may include different dimensions depending on the culture. To achieve construct equivalence, preliminary investigation on the meaning of the construct of interest in each country or cultural context is necessary. This did not happen in the present dissertation because it was expensive and time consuming. However,

involving a multicultural researcher who was familiar with both German and Iranian cultures contributed to partially tackle this issue. Nevertheless, the results of the present dissertation should be carefully interpreted concerning measure or construct equivalency. For instance, this issue might be a possible reason that the reliability of the self-report (BSCS) used in the *Study 2* dropped in the Iranian sample.

Another important limitation in cross-cultural/national research is the reference group effect. A reference group can be any group that individuals use as a standard for evaluating themselves and their behaviors (Heine et al. 2002; Schild, Ścigała, Zettler, 2018). For instance, a person might overestimate their math skills when comparing themselves with classmates who have weaker skills. However, in another classroom with classmates who have strong math skills, the same person might underestimate their math skills. This issue is relevant for many between-group studies and may even be a bigger concern in cross-cultural studies including the present dissertation. In the present dissertation, the reported self-regulation abilities of children might be compared to different reference groups in Germany and Iran. Hence, the difference in self-control informant-reports between German and Iranian parents in *Study 3,* might be due to the reference group effect. Accordingly, the results of the present dissertation should be carefully interpreted concerning the possible confounding reference group effect in comparisons of mean questionnaire responses between German and Iranian samples.

All in all, the self- or parent-reports used in the present dissertation were designed and validated for Western countries, thus, Iranian participants might have interpreted the measured construct differently or/and compared themselves with different standards and group references than participants in Western countries. Therefore, although the reliability of the questionnaires used in the present dissertation are acceptable for both German and Iranian samples, caution is required when interpreting the mean value comparisons between the groups due to the relatively low reliability in the Iranian sample.

4.4 Directions for Future Studies

Despite the importance of the findings of the present dissertation on the different self-regulation abilities of preschool children in Germany and Iran, it still remains unclear how specific cultural variables can lead to this difference. Thus, future studies may wish to systematically include culture-specific factors (e.g., socialization practices such as mother-child

and teacher-child interactions), which are related to the development of self-regulation abilities and compare their influences on self-regulation abilities across countries. Furthermore, how the relationship between cultural context and self-regulation changes during development needs to be uncovered. Hence, another potential research direction would be the use of longitudinal studies to understand developmental changes in relation to self-regulation ability across different cultural contexts. Accordingly, the results of the present dissertation give rise to a number of interesting developmental questions, which could be considered in future research. For instance, at what age do differences in self-regulation begin to emerge between independence-oriented and interdependence-oriented contexts? Is there a critical period in which differences in self-regulation are particularly sensitive to cultural context?

Furthermore, in general, inhibitory control is valued in most religions but the importance of religion in a socialization context (i.e., religiousness) might differ between Germany and Iran. The relationship between religion and self-regulation has been explored in previous research (McCullough & Willoughby, 2009). Previous studies suggested that religious values can play a central role for everyday interactions between individuals (McCullough & Willoughby, 2009) and create a context for the implicit learning of behavioral rules for children (Heikamp, 2014). Thus, religiousness may be an important contextual variable that can provide further information about cultural differences in the development of self-regulation. Future cross-cultural/national studies on the development of self-regulation could shed light on the extent to which religiousness affects socialization contexts that influence the ability to self-regulate.

In addition, *Study 2* investigated the association between self-regulation and mathematics performance in the German and Iranian college students who lived in Germany and Iran respectively. Including Iranian students residing in Germany and German students living in Iran is also recommended in order to disentangle the effect of cultural context/country from schooling systems on self-regulation.

With regard to the unique methodological challenges of cross-cultural/national studies, future research may wish to consider preliminary research on the meaning of the construct of interest in each cultural context in order to establish construct equivalence. Additionally, a broad review of the existing national and country-specific literature as well as the use of multicultural research teams and international collaboration is strongly recommended. Following an examination, the construct equivalence in each cultural context, an attempt should be made to

recruit representative samples within the culture and to adapt the measure to each cultural context through translation equivalence in order to accomplish measure equivalence. Translation procedure should take into account the differences identified in construct equivalence. Lastly, data collection equivalence can also be achieved by using identical data collection procedures and making the test settings and experimental instructions equivalent in the countries or cultural contexts under study.

4.5 Conclusion

The present dissertation contributed to the better understanding of the context-sensitivity of self-regulation and its association with academic performance. The findings suggest that self-regulation abilities might differ at the preschool age in distinct countries, however, the relationship between self-regulation and mathematics performance in young adults might be similar between countries when field of study is taken into account. Based on our results indicating better performance of German preschool children than Iranian preschool children in the delay of gratification task, the assumption discussed in the previous cross-cultural studies that children from interdependence-oriented contexts generally show a greater level of self-regulation ability than children from independence-oriented contexts is to be viewed critically.

This contribution also points to the importance of context-sensitive approaches towards investigating self-regulation and suggests that interest in cross-cultural/national studies, which has only recently begun to grow should be continued and consolidated. Future studies can consider cultural factors, which differentiate Middle Eastern countries from other interdependent countries (e.g., East Asian or African countries) and shed light on the specific cultural factors underlying self-regulation differences at different ages across countries.

5. SUMMARY (GERMAN)

Selbstregulation ist ein multidimensionales Konstrukt, das als die Fähigkeit, Gedanken, Emotionen und Verhaltensweisen zu kontrollieren, definiert wird und positiv mit der akademischen Leistung verbunden ist. Darüber hinaus ist die Selbstregulation kontextsensitiv, was darauf hindeutet, dass Selbstregulationsfähigkeiten von Einzelnen in verschiedenen Kontexten unterschiedlich sein könnten. Deutschland und der Iran bieten zwei verschiedene Kontexte mit unterschiedlichen kulturellen Merkmalen, die die Selbstregulation beeinflussen können. Bis heute wurde die Selbstregulation jedoch hauptsächlich in westlichen Ländern und folglich in jeweils ähnlichen kulturellen Kontexten untersucht; es fehlt daher an Forschung, die sich mit der Selbstregulation und ihrem Zusammenhang mit akademischen Leistungen in nichtwestlichen Ländern beschäftigt. Die vorliegende Dissertation untersuchte daher die Selbstregulation und ihren Zusammenhang mit der (vor-)akademischen Leistung in Deutschland und im Iran mit dem Ziel, zum besseren Verständnis der Kontextsensitivität der Selbstregulation beizutragen. Die Entwicklung der Selbstregulation von Studierenden als junge Erwachsene, ist tief in den Kontext eingebettet, in dem sie aufgewachsen sind, außerdem befinden sie sich noch in iher akademischen Ausbildung. Obwohl das Verhältnis von Selbstregulation und akademischer Leistung für Kinder bereits gut untersucht wurde, sind Studien, die dieses Verhältnis bei Erwachsenen untersuchen, eher selten und bedürfen daher weiterer Forschung. Entsprechend untersuchte im ersten Schritt Studie 1 den Zusammenhang verschiedener Aspekte der Selbstregulation und der Mathematikleistung bei jungen Erwachsenen. Im zweiten Schritt verglich Studie 2 den Zusammenhang zwischen Selbstregulation und Mathematikleistung bei jungen Erwachsenen in zwei verschiedenen Ländern (Deutschland und Iran). Daher sollten Studie 1 und Studie 2 am besten zusammen betrachtet werden.

Darüber hinaus haben die Ergebnisse von Längsschnittstudien in westlichen Ländern gezeigt, dass die akademische Leistung durch die Selbstregulationsfähigkeit des Kindes im Vorschulalter vorhergesagt werden kann. In Anbetracht der unterschiedlichen Auswirkungen von Kontexten auf die Entwicklung der Selbstregulation, deuten diese Ergebnisse darauf hin, dass es Unterschiede zwischen deutschen und iranischen Kindern im Vorschulalter in Bezug auf die Selbstregulationsfähigkeiten geben könnte, die ihre akademische Leistung in Zukunft beeinflussen könnten. Dementsprechend untersuchte Studie 3 im dritten Schritt die

Selbstregulierungsfähigkeit deutscher und iranischer Kinder im Vorschulalter vor Beginn ihrer formalen Ausbildung.

Studie 1 zielte darauf ab, den Zusammenhang zwischen Selbstregulation und Mathematikleistung bei jungen Erwachsenen zu untersuchen. Es wurden verschiedene Aspekte der Selbstregulation und der Mathematikleistung an 40 deutschen Studierenden, von denen 33 weiblich waren, im Alter zwischen 19 und 21 Jahren untersucht. Die Ergebnisse zeigten, dass die Selbstregulation wider Erwarten keine Vorhersage der Mathematikleistung lieferte, die Selbstkontrolle jedoch signifikant positiv mit der Mathematikleistung der Studierenden zusammen hing. Die Ergebnisse deuten darauf hin, dass Studierende mit größeren Selbstkontrollfähigkeiten besser in der Lage sein könnten, sich auf die Aufgaben zu konzentrieren und unerwünschte Gedanken oder ablenkende Informationen zu ignorieren und sie somit schneller auf die mathematischen Probleme reagieren konnten. Insgesamt zeigten die Ergebnisse, dass der zuvor entdeckte positive Zusammenhang zwischen Selbstkontrolle als Aspekt der Selbstregulation und mathematischer Leistung bei Kindern auch bei jungen Erwachsenen gültig ist.

Studie 2 zielte darauf ab, den Zusammenhang zwischen Selbstregulation und Mathematikleistung bei jungen Erwachsenen in zwei verschiedenen Ländern (Deutschland und Iran) zu untersuchen. Dafür wurden 44 iranische Studierende hinsichtlich ihrer Selbstregulationsfähigkeit und ihrer Mathematikleistungen untersucht und die Ergebnisse mit den im Rahmen von *Studie 1*, die deutsche Studierende untersuchte, gewonnenen Daten verglichen. Die Selbstregulation wurde mit dem gleichen Maß bewertet, das auch in Studie 1 zur Beurteilung der Selbstkontrolle als Aspekt der Selbstregulation verwendet wurde. Die mathematische Leistung wurde ebenfalls mit der gleichen mathematischen Aufgabe gemessen, die auch in Studie 1 verwendet wurde. Darüber hinaus wurde in dieser Studie auch das Studienfach der Probanden berücksichtigt. Die Ergebnisse dieser Studie zeigten, dass die Selbstregulation die Mathematikleistung nur bei deutschen und nicht bei iranischen Studierenden vorhersagte. Wenn für die iranischen Studierenden jedoch das Studienfach berücksichtigt wurde, prognostiziert die Selbstregulation auch die Mathematikleistung in der Untergruppe der iranischen Studierenden des Fachbereichs Humanwissenschaften. Darüber hinaus unterschied sich der Zusammenhang zwischen Selbstregulation und Mathematikleistung bei deutschen Studierenden weder von der gesamten iranischen Gruppe noch von den iranischen Studierenden

der Humanwissenschaften signifikant. Zusammenfassend lässt sich sagen, dass die Ergebnisse zeigen, dass der Zusammenhang zwischen Selbstregulation und Mathematikleistung zwischen deutschen und iranischen Studierenden ähnlich ist, wenn man die Art des Studiengangs berücksichtigt.

Studie 3 zielte darauf ab, die Selbstregulationsfähigkeit deutscher und iranischer Vorschulkinder mit einer Aufgabe zum Belohnungsaufschub zu untersuchen. Die Selbstregulationsfähigkeit wurde als Leistung sowie durch Strategien (d.h. Fokussierung, Zurückhaltung, Ablenkung), die von Kindern im Rahmen des Belohnungsaufschubs (Mischel, 1989) gezeigt wurden, operationalisiert. Das Verhalten von Kindern während der Aufgabe wurde auf Video aufgezeichnet und später hinsichtlich der verwendeten Strategien, welche die Aufmerksamkeit auf eine Belohnung hin oder weg von ihr lenkten, bewertet. Die Ergebnisse zeigten, dass deutsche Kinder bei der Aufgabe zum Belohnungsaufschub länger warteten als iranische Kinder. Strategien, die die Aufmerksamkeit auf die Belohnung lenkten, untergruben die Leistung in der Verzögerung der Befriedigungsaufgabe bei deutschen, aber nicht iranischen Kindern. Außerdem verwendeten die deutschen Kinder mehr Strategien der Zurückhaltung als die iranischen Kinder, um sich selbst davon abzuhalten, die Belohnung zu berühren. Diese Ergebnisse deuten darauf hin, dass die Selbstregulationsfähigkeiten von Kindern im Vorschulalter in verschiedenen Ländern unterschiedlich sein könnten.

Insgesamt liefern diese Ergebnisse empirische Belege für die wichtige Rolle der bisher wenig untersuchten Kontextabhängigkeit der Selbstregulation. Die Ergebnisse zeigten, dass sich die Selbstregulationsfähigkeiten von deutschen und iranischen Kindern im Vorschulalter unterschieden. Der Zusammenhang zwischen Selbstregulation und der Mathematikleistung von jungen Erwachsenen war jedoch in beiden Ländern ähnlich, wenn das Studienfach berücksichtigt wurde.

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7. DECLARATION ON THE CONTRIBUTION OF CO-AUTHORS

Study 1: Planning and Self-Control, but not Working Memory, Directly Predict Multiplication Performance in Adults

Author	Author position	Scientific ideas %	Data generation %	Analysis & interpretation %	Paper writing %
Parvin Nemati	Doctoral Candidate	20	50	40	60
Johanna Schmid	Dr.	10	-	10	10
Mojtaba Soltanlou	Dr.	10	-	-	10
Julian-Till Krimly	M.Sc.	-	50	10	-
Hans-Christoph Nuerk	Prof.	30	-	20	10
Caterina Gawrilow	Prof.	30	-	20	10
Title of paper:	Planning and Self-Control, but not Working Memory, Directly Predict Multiplication Performance in Adults				
Status in publication process:	Published: Nemati, P., Schmid, J., Soltanlou, M., Krimly, J. T., Nuerk, H. C., & Gawrilow, C. (2017). Planning and self-control, but not working memory, directly predict multiplication performance in adults. *Journal of Numerical Cognition*, *3*(2), 441-467.				

I confirm that the above-stated is correct.

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Date, Signature of the candidate

I/We certify that the above-stated is correct.

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Date, Signature of the doctoral committee or at least of one of the supervisors

Study 2: Self-Regulation and Mathematics Performance in German and Iranian College Students

Author	Author position	Scientific ideas %	Data generation %	Analysis & interpretation %	Paper writing %
Parvin Nemati	Doctoral Candidate	50	90	40	60
Caterina Gawrilow	Prof.	50	10	10	10
Hans-Christoph Nuerk	Prof.	-	-	10	10
Jan Kühnhausen	Dr.	-	-	40	20
Title of paper:	Self-Regulation and Mathematics Performance in German and Iranian College Students				
Status in publication process:	Submitted to the Neuro-cognitive Architecture of Numerical Cognition and Its Development special issue of the journal of Frontiers in Human Neuroscience				

I confirm that the above-stated is correct.

_____

Date, Signature of the candidate

I/We certify that the above-stated is correct.

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Date, Signature of the doctoral committee or at least of one of the supervisors

Study 3: Delay of Gratification Performance of Iranian and German Preschool Children

Author	Author position	Scientific ideas %	Data generation %	Analysis & interpretation %	Paper writing %
Parvin Nemati	Doctoral Candidate	50	60	40	60
Jan Kühnhausen	Dr.	-	-	40	10
Azar Mehri	Dr.	-	10	-	5
Johanna Schmid	Dr.	10	-	-	5
Zahra Mohammadi	M.Sc.	-	30	-	-
Hans-Christoph Nuerk	Prof.	-	-	10	10
Caterina Gawrilow	Prof.	40	-	10	10
Title of paper:	Delay of Gratification Performance of Iranian and German Preschool Children				
Status in publication process:	Not Published				

I confirm that the above-stated is correct.

_____

Date, Signature of the candidate

I/We certify that the above-stated is correct.

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Date, Signature of the doctoral committee or at least of one of the supervisors