THE VALIDITY OF THE JUNIOR BRIXTON SPATIAL RULE ATTAINMENT TEST IN 6- TO 8-YEAR-OLD TURKISH CHILDREN

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The Validity of the Junior Brixton Spatial Rule Attainment Test in 6- to 8-Year-Old Turkish Children

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Thesis Abstract

Nilay Şentürk, "The Validity of the Junior Brixton Spatial Rule Attainment Test in 6- to 8-Year-Old Turkish Children"

The present study investigated the validity of an executive function (EF) measure, the Junior Brixton Spatial Rule Attainment Test (JBSRAT) in relation with another EF tool, the Wisconsin Card Sorting Test (WCST), a working memory (WM) test, namely Backward Digit Span (BDS), and a fluid intelligence (FI) measure, which is the nonverbal battery of Cognitive Abilities Test (CogAT®). Aims of the study were to explore (1) the internal structures of the JBSRAT and the WCST; (2) the relationships among EF, WM, and FI; and (3) effects of demographic variables (i.e. age, gender, grade, type of school, and maternal education) on measures of EF, WM, and FI. One hundred and twenty five 6- to 8-year-old Turkish students participated, but data of 121 students were used in the statistical analyses. Results suggested that the JBSRAT and the WCST have similar components: concept formation and perseveration. The concept formation scores in two EF tests were correlated, but perseveration factors were distinct from each other. Furthermore, there was a significant correlation between BDS and nonverbal CogAT® ($r = .42$). Nonverbal CogAT® was also significantly correlated with 6 scores of the WCST and 2 scores of the JBSRAT, indicating a significant relationship between EF and FI. Finally, it is found that maternal education was a significant covariate for 4 scores of the WCST, 3 scores of the JBSRAT, and the BDS score. Effects of age, gender, grade, and type of school were not statistically significant for any of the EF, WM, and FI measures, except the effect of gender on the JBSRAT. In JBSRAT, the main effect of gender and the interaction between age and gender were statistically significant.

Tez Özeti

Nilay Şentürk, "6-8 Yaş Türk Çocuklarda Çocuklar için Brixton Testi'nin Geçerliği"

Bu çalışma, bir yürütücü işlev (Yİ) testi olan Çocuklar için Brixton Testi'nin (ÇBT), başka bir Yİ testi olan Wisconsin Kart Eşleme Testi (WKET), bir işleyen bellek (İB) testi olan Ters Sayı Dizisi (TSD) ve de bir akışkan zeka (AZ) testi olan Bilişsel Yetenekler Testi'nin (CogAT®) sözel olmayan bataryası ile olan ilişkileri üzerinden geçerliğini incelemektedir. Çalışmanın amaçları şunlardır: (1) ÇBT ve WKET'in içyapılarını incelemek, (2) Yİ, İB ve AZ arasındaki ilişkiyi incelemek, (3) bazı demografik özelliklerin (örneğin, yaş, cinsiyet, sınıf, okul türü ve anne eğitimi) bu çalışmadaki Yİ, İB ve AZ testleri üzerindeki etkisini incelemek. Çalışmaya, 6-8 yaşlarında 125 çocuk katılmıştır, fakat 121 çocuğun datası analizlerde kullanılmıştır. Sonuçlara gore, ÇBT ve WKET'in içyapıları kavram oluşturma ve perseverasyon faktörlerinden oluşmaktadır. Testlerin kavram oluşturma puanlarının birbirleriyle ilişkili olduğu bulunurken, perseverasyon faktörlerinin birbirlerinden farklı olduğu gözlemlenmiştir. Ayrıca, TSD ve sözel olmayan CogAT® arasında anlamlı bir korelasyon bulunmuştur (r = .42). Sözel olmayan CogAT®'in WKET skorlarının 6 tanesiyle ve ÇBT skorlarının 2 tanesiyle yaptığı korelasyonlar, Yİ ve AZ yetileri arasında anlamlı bir ilişki olduğunu işaret etmektedir. Son olarak, anne eğitimi, WKET skorularının 4 tanesi için ve ÇBT skorlarının 3 tanesi için anlamlı bir eşdeğişken faktör olarak bulunmuştur. Yaş, cinsiyet, sınıf ya da okul türü, Yİ, İB ve AZ testlerindeki performans üzerinde anlamlı bir etki göstermemiştir. Sadece ÇBT performansları üzerinde cinsiyetin etkisi ve yaş-cinsiyet etkileşimi anlamlı bulunmuştur.

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CONTENTS

TABLES

CHAPTER 1

INTRODUCTION

The term executive function (EF) refers to the orchestration of all cognitive processes involved in goal-directed behavior and problem solving (Welsh & Pennington, 1988). Executive functions are in the interest areas of not only cognitive and neuropsychological disciplines, but also the clinical psychology due to the fact that deficits in EF is fundamental in various psychological disorders, i.e., Attention Deficit Hyperactivity Disorder (ADHD), Tourette syndrome, autism spectrum disorder, learning disability, schizophrenia and so on (Barkley, 1997; Channon, Pratt, & Robertson, 2003; Griffith, Pennington, Wehner, & Rogers, 1999; Koren et al., 1998; Shallice, Marzocchi, Coser, Savio, Meuter, & Rumiati, 2002; Sullivan et al., 1993; Zelazo, Carter, Reznick, & Frye, 1997).

Although EF impairment is crucial in various neuropsychological disorders, Gioia, Isquith, and Guy (2001) stressed that “there is no singular, core disorder of executive function” (p. 324). Executive functions include several subdomains, and different component(s) of EF is impaired in each specific disorder. Hence, it is not possible to define a single, consistent executive dysfunction. Rather, the crucial issue is to define which specific components of EF are impaired in certain disorders (Gioia et al., 2001). For instance, Barkley (1997) argued that it is the behavioral inhibition mechanism that is impaired in ADHD. In addition, Channon et al. (2003) indicated that patients with Tourette’s syndrome were impaired only in EF tests specifically measuring inhibition and strategy generation (i.e., Hayling Sentence Completion Test, Stroop test, and Letter Fluency Test). For this reason, assessment tools for EF should be considered as a screening instrument for different EF domains (i.e., shifting, inhibition, concept formation, and working memory), rather than a tool for diagnosis.

Nevertheless, not all of the EF measures include all of the components of EF (Miyake, Friedman, Emerson, Witzki, & Howerter, 2002). For instance, Stroop tasks mainly assess one's inhibition ability; Verbal or Design Fluency Tests measure fluency; and reasoning tasks (i.e., Raven's Progressive Matrices) provide information about one's estimation and reasoning abilities (as cited in Miyake et al., 2002). On the other hand, there are measures including more than one EF subdomain. For instance, Wisconsin Card Sorting Test (WCST) measures abilities of concept formation and shifting (Berg, 1948), or Brixton Spatial Rule Attainment Test measures rule conceptualization and shifting abilities (Burgess & Shallice, 1996). For this reason, investigations on EF measures are necessary not only for research purposes, but also for the clinical use since defining one's strengths and weaknesses in executive functioning in different psychological disorders is a prerequisite for clinical intervention.

Considering these, the present study aimed to investigate the validity of an EF measure, the Junior Brixton Spatial Rule Attainment Test (JBSRAT), through statistical comparisons with another EF measure (the WCST), a working memory (WM) measure (Backward Digit Span), and a nonverbal reasoning test (the Cognitive Abilities Test-Nonverbal Battery).

Executive Functions

EF is a higher-order cognitive construct, which is widely explored in different clinical or non-clinical, and adult or children samples. Although there is a lack of consensus on the precise definition of EF, a widely accepted view is that the function of EF is to maintain a group of inter-related processes in order to accomplish purposeful, goal-directed behavior (Benton, 1994; Lezak, 1982; Miyake et al., 2002; Welsh, 2002). For instance, Zelazo and Frye (1998) indicated that the ultimate reason of EF is "deliberate problem solving" (p. 122). Besides, Luria mentioned that executive functions refer to the higher-order cognitive processes "involved in planning, regulation, and verification of activity" (1966; as cited in Pennington, Groisser, & Welsh, 1993, p. 513). These inter-related processes involved in the executive functions are various, but most generally accepted elements include anticipation, goal-maintenance, planning, initiation of the goal-directed behavior, emotional and behavioral self-regulation, allocation and maintenance of attention, and successful use of feedback in novel situations (Anderson, 2002).

Models of Executive Functions: Behavioral and Cognitive Definitions

Lezak (1982) considered EF as an umbrella embracing different inter-related processes involved in goal-directed behavior, and defined four major classes of behaviors requiring executive capacities: (1) specifying needs and goals of an action; (2) planning, which necessitated the organization of necessary action sequences and possible alternatives; (3) strategy generation in order to reach goals, and (4) performing the generated strategies efficiently. The last step requires being self-reflective and self-corrective in order to accomplish the goal-directed behavior.

Likewise, Anderson (2002) proposed four distinct but interrelated domains of executive functions, with respect to the model of Alexander and Stuss (2000, as cited in Anderson, 2002): (1) attentional control, (2) information processing, (3) cognitive flexibility, and (4) goal-setting. The attentional control involves monitoring and regulation of correct actions in the correct order through selective and sustained attention, and inhibition of inappropriate responses. Information processing involves the integration of neuronal connections with frontal lobe processes, and it manifests itself with respect to speed, efficiency and the quality of the output. The cognitive flexibility domain contains the abilities of shifting between different responses; monitoring oneself in the case of mistakes; producing alternative responses; and dividing attention and integrating different sources of information simultaneously. In this regard, cognitive flexibility domain is argued to benefit from WM capacity (Anderson, 2002). Finally, the goal setting domain is about strategy generation, and initiation and maintenance of goal-directed actions efficiently. Anderson (2002) argued that these domains are discrete functions operating in an integrative manner since they are related to specific frontal systems.

Zelazo et al. (1997) used the problem-solving framework in their conceptualization of EF. Zelazo and Frye (1998) stated that EF is generally defined with respect to its eventual outcome, which is basically problem solving. Their problem-solving framework includes four distinct phases of EF: (1) problem representation, which involves the mental representation of the problem; (2) planning the action sequences; (3) execution, which requires holding the plan in mind and carrying out it in the planned sequences; and (4) evaluation of the consequences of the rule use in order to decide whether the problem is solved or not (1997). In the evaluation phase, one should revise the action steps through detecting errors and correcting them in order to finalize the problem solving process.

Zelazo and Frye (1998) claim that conducting these phases of executive functions necessitates conscious reflection on one's plans, and the degree of this reflection is a result of major developmental transitions. According to Zelazo and Frye's theory of Cognitive Complexity and Control (CCC), age-related changes in EF are related to children's ability to hold complex hierarchical rules in mind when formulating plans, executing them, and evaluating the process (1998). Furthermore, they argued that use of complex rules is related to the conscious reflection. In other words, through reflection on the represented rules, children become able to compare and contrast the represented rule with the other rules, integrate them, and formulate higher rules, i.e., integrating conditional statements into a one complex rule. Hence, there are age-related differences between children's ability to hold and formulate complex rules.

Additionally, Barkley's definition of the term EF has a behavioral basis (2001). Barkley (2001) states that EF refers to "the major classes of behavior toward oneself used in self-regulation" (p. 5). In this regard, Barkley (1997) emphasized behavioral inhibition as the underlying mechanism of four major executive functions: prolongation, separation of affect, internalization of speech, and reconstitution. Prolongation refers to the ability to represent events symbolically in mind and use them backward and forward in time when necessary. Hence, prolongation is basically the WM capacity, which sustains maintenance of information in mind, initiation of complex chains of behaviors, retrospective and prospective thinking, sense of time, and organization of cross-temporal behavior (Barkley, 1997). Secondly, separation of affect refers to the regulation of affect, motivation, and arousal. It is the ability to separate emotional component of the event in order to generate neutral responses in the case of emotionally provocative events, i.e., remaining calm when you are angry. The third EF in Barkley's model, the internalization of speech, refers to the inner discussion of possible responses and their consequences, such that language turns to oneself (reflection) and provides guidance to the individual for evaluating the effective sequences of actions (Barkley, 1997). Finally, reconstitution, the forth EF in this model, involves two processes: analysis and synthesis. Through analysis, individual decomposes the sequences of events into its parts. Then, through synthesis, those decomposed parts are manipulated and reconstituted into a new sequence of events as responses. In this regard, reconstitution is involved in generating new action plans, creating problem-solving formulas, and generating alternative responses through the processes of analysis and synthesis (Barkley, 1997). Barkley (1997, 2001) argues that behavioral inhibition does not directly lead to these four executive functions, but mediates them. In other words, behavioral inhibition is involved within those executive functions as an underlying component, rather than being an upper process directly causing those functions. Nevertheless, Barkley (1997) also mentioned that the link between behavioral inhibition and the executive functions is not clear since behavioral inhibition and executive functions have distinct influences on motor control.

Roberts and Pennington (1996) claimed that not the behavioral inhibition alone, but the interaction of WM and inhibition mechanisms are involved under the executive functioning ability. In this regard, executive functioning requires the inhibition of prepotent inappropriate responses, and the use of available information in order to formulate the correct/adaptive responses. In this kind of formulation, it is necessary to use active attention, hold relevant information in mind, and manipulate that information for the sake of solution (Roberts & Pennington, 1996). Although Pennington, Bennetto, McAleer, and Roberts (1996) argue that WM capacity and inhibitory control mechanisms are distinct processes, they also indicate that the inhibitory mechanism is an essential component of WM operations. In this regard, Pennington and colleagues (1996) claim that executive functions involve WM capacity as the basic core mechanism, which embraces inhibition in its essential constitution.

Models of Executive Functions: Neural Correlates

Studies of Luria demonstrated the link between executive functions and the prefrontal cortex (PFC). For instance, Luria (1973) observed that damage to the prefrontal cortex (i.e., lesions) does not lead to problems in sensory, motor or speech functions, but leads to impairments in organization of goal-directed, conscious behavior (i.e., results in impulsive behavior). In the model of Luria, three "functional systems" are defined with respect to functions of different brain regions (as cited in Scheller, 2008), and in each of these systems, individual needs not only feedback about the effect of his/her behavior, but also "feed-forwards" in order to generate plans and strategies (Luria, 1973, p. 959). The first functional system regulates arousal, and enables us to focus our attention. This system is anatomically associated with the brain stem, diencephalons, and the medial regions. The second functional system is responsible for analysis, management, and the storage of stimuli, and associated with the occipital, parietal, and temporal lobe regulation. Finally, the third functional system, which is the frontal lobe regulation, allows us to generate hypothesis, make plans, organize behaviors, and self-monitor ourselves, so that it basically refers to the executive functioning ability. Luria (1973) considered the PFC as the crucial anatomical structure regulating the mental and behavioral actions within the third functional system, so it is expected that the individual would lose his/her behavioral regulation ability in the case of damage to the PFC.

Similarly, Fuster (2001) focused on the PFC and stressed its importance for higher order cognitive functions like "propositional speech and reasoning" (p. 319). Fuster (2001) considered PFC with respect to three functional regions (orbital, medial, and lateral), and claimed that orbital and medial PFCs are associated with emotions, whereas the duty of lateral PFC is to temporarily organize actions, speech, and reasoning. In this regard, Fuster (2001) argued that what is impaired in patients of Luria's studies is lateral PFC, which is associated with speech and reasoning.

Stuss and Levine (2002) also explained different facets of prefrontal functioning with respect to a neuroanatomical distinction. They claim that the ventral prefrontal cortex (VPFC) and the dorsolateral prefrontal cortex (DLPFC) are functionally distinct, such that the VPFC is related to the limbic system involved in emotional processing, whereas the DLPFC is associated with the hippocampus, and sustains spatial and conceptual reasoning abilities. Stuss and Levine (2002) argue that this neuroanatomical distinction within the frontal system leads to different cognitive processes associated with either the VPFC or the DLPFC. For instance, speech problems, control of memory (i.e., WM capacity), and attentional processes are related to the DLPCF, whereas emotion regulation, effect of reinforcement, decision-making, inhibition, empathy, sympathy, and humor are associated with the VPFC functioning. This differentiation refers to the differentiation of "cool" and "hot" aspects of executive functions. The "cool" aspects of EF refer to the emotionally neutral cognitive processes, such as WM capacity, attention, or language (the DLPFC functioning) (Garon, Bryson, & Smith, 2008). The “hot” aspects of EF are affective decision-making, emotional self-regulation, inhibition, and personal interpretations (the VPFC functioning) (Bechara, Tranel, Damasio, & Damasio, 1996; Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Damasio, Damasio, & Lee, 1999). For instance, Bechara and colleagues (1996) focus on the ventromedial PFC in order to examine the relationship between somatic states and decision-making process via performance on the Iowa’s Gambling Task. In this task, there are two kinds of decks: the advantageous deck and the disadvantageous desk. When the participant chooses a card from the disadvantageous desk, s/he loses more. The participant is not informed about the characteristic of the desk, but s/he should realize it throughout the task. After a few losses, normal participants generate anticipatory skin conductance responses (SCRs) before selecting from the disadvantageous decks, and they begin to avoid from those decks. However, patients with ventromedial PFC damage do not generate an anticipatory SCR, and continue to choose from the disadvantageous deck. The study of Bechara and colleagues (1996) suggest that in the case of damage to the ventromedial PFC, the participant cannot access the information of emotional state related to the reward or punishment after his/her response. Consequently, it is argued that the decision-making is a complex processes involving not only the cognitive aspects of EF, but also uses the emotional states (Bechara et al., 1996; Bechara et al., 1997; Bechara et al., 1999).

Supervisory Attentional System (SAS): A Model for Cognitive, Behavioral and Neural Processes of Executive Functions

Shallice (1982) claims that although Luria's concept of functional system is clinically beneficial in explaining specific disorders such as lesions in frontal lobes, it is not sufficient because it lacks cognitive processes. Shallice argued that there has been little contribution from cognitive psychology to the understanding of higher-order cognitive dysfunctions. In this regard, Norman and Shallice (1980, as cited in Shallice, 1982) proposed the Supervisory Attentional System (SAS) model in order to provide a deeper understanding of the higher-order cognitive functions. In this model, the focus is on a higher-order "supervisory system" that forms and executes necessary actions in novel situations, and it is argued that "prefrontal cortex is the seat of" this system (Shallice & Burgess, 1996, p. 1405). This model is crucial in the EF literature since it not only defines the interrelated processes and their behavioral manifestations in daily life, but also assigns an executive system to operations them.

According to this model, the basic unite of action is "schema", which is defined as "a unit that can control a specific overlearned action or skill such as drinking from a container, doing long division, making breakfast, or finding one's way home from work" (Shallice, 1982, p. 199). Schemas can be independent of each other, and they are used according to two principles: contention scheduling and the supervisory attentional system (SAS). In routine situations, the basic mechanism is the contention scheduling, which is selecting appropriate schemas and inhibiting the inappropriate ones. However, in novel situations, contention scheduling is not enough, so that a higher system, SAS, is activated. SAS is involved in (1) decision-making, (2) error correction, (3) novel sequences of action, (4) anticipation of a dangerous situation, and (5) overcoming a habitual response (Chan, Shum, Toulopoulou, & Chen, 2008). With the involvement of the PFC, SAS uses perceptual, motor, and memory processes in order to organize new information in novel situations, and operate on the existing schemas (Shallice, 1982). SAS orchestrates a new adaptive response through planning, maintaining novel action sequences, and inhibition of prepotent responses.

Shallice and Burgess (1996) argue that SAS is a single system, which is associated with the PFC, but not a single type of process. The function of SAS is to integrate a variety of processes carried out in different subsystems. In this regard, Shallice and Burgess (1996) define 8 processes involved in the construction of a temporarily new schema. The first process is the operation of a temporarily active schema. This process uses WM capacity in order to hold this schema since it is not automatically triggered in a novel situation. The second process is to monitor the effectiveness of the schema in that situation, and the third process involves decision of either rejection or modification of this schema. Then, spontaneous strategy generation, which is the execution of previously held methods, takes place. However, in this novel situation, those spontaneously generated strategies would not be sufficiently helpful, so that they would lead to a sense of dissatisfaction. At this point, individual needs to benefit from the problem-solving processes in order to generate new strategies. Hence, the fifth process involves the control of action sequences that are required in that particular novelty. Afterwards, the sixth process involves the "evaluative moment", which provides management of goals and the expectancy about the results (De Groot, 1966, as cited in Shallice & Burgess, 1996, p. 1406). In the final stage, processes for operation and management of the appropriate strategy are used. In this regard, the seventh process is to generate conscious intentions, so that the strategies can be used in a later time. Finally, the eighth process is the episodic memory retrieval, which is helpful in remembering the materials of related experiences in novel situations.

Burgess and colleagues stated that SAS involvement is required in multi-tasking performance, such as when more than one task is involved in a certain situation, when a person should engage in a particular task in a particular time period, when the task requires different task characteristics, when the person should decide on the appropriate strategy in a certain task/situation, or when there is no immediate feedback about the performance (as cited in Chan et al., 2008). However, it is argued that not all of the EF measures include all of these features, but the ones that are developed with respect to the SAS model such as the Brixton Spatial Rule Attainment Test, the Six Elements Test, the Hayling Sentence Completion Test, and the Sustained Attention to Response Task (Burgess & Shallice, 1996; Chan et al., 2008; Shallice & Burgess, 1996). These EF tasks aim to capture different components of executive functions, such as planning, strategy generation and monitoring, and inhibition of inappropriate semantic or action responses.

The Unity and Diversity Approaches to the Nature of Executive Functions

Different models approach EF from different perspectives, but they are not mutually exclusive. In all of the models, EF is defined as a group of higher-order processes orchestrating the domain-specific, lower-level processes in conducting purposeful, goal-directed, problem-solving behaviors in novel situations. On the other hand, there is an ongoing debate on the nature of executive functions in the literature (Baddeley, 1996; Duncan, Johnson, Swales, & Freer, 1997; Godefroy, 2003;

Kimberg, D'Esposito, & Farah, 1997; Miyake et al., 2002). For instance, several researchers claim that the nature of EF involves a common, unifying mechanism, basically related to the integrative nature of frontal system (i.e., Duncan et al., 1997; Kimberg et al., 1997), whereas other researchers argue for the diversity of executive functions with respect to the non-unitary processes involved in frontal lobe functioning (Baddeley, 1996; Godefroy, 2003). Therefore, factorial studies were conducted in order to understand the nature of EF, and it is consistently found that EF tasks consist of separate factors, which are mildly correlated to each other. For instance, Miyake et al. (2002) examined the unitary and non-unitary nature of executive functioning via focusing on three commonly indicated EF abilities: shifting, updating, and inhibition. They applied confirmatory factor analysis (CFA) and found that those abilities are separately related to different EF measures although they share a commonality. In this regard, the study of Miyake and colleagues (2002) proposes that the executive functions of shifting, updating, and inhibition are separate abilities that share an underlying commonality—supporting both unitary and non-unitary accounts. Additionally, Bull, Espy, and Wiebe (2008) examined the relationship among short-term memory (STM), WM, EF, and mathematical achievement. They indicated that under the rubric of term executive functions, shifting attention, inhibition, and goal-planning and monitoring stand as significant skills, indicating that separate processes are grouped under the rubric of executive functioning ability. Besides, Yeniçeri and Altan-Atalay (2008) explored the internal structure of an EF test, the WCST, and found that it consists of 3 components: perseveration, set maintenance, and conceptual thinking. Consequently, different studies indicate that EF can be conceptualized with different factorial components (i.e., concept formation, shifting, and WM) rather than a single-factor.

Working Memory

Working memory stands as a crucial capacity in EF models. For instance, the concept of prolongation in the Barkley's model of EF refers to one's WM capacity (1997). Similarly, concepts of purposive action (Lezak, 1982) and cognitive flexibility (Anderson, 2002) benefit from WM capacity since both of them include holding the action-oriented plans in mind, and maintaining and manipulating them with respect to necessary goals. Additionally, other theoreticians (i.e., Pennington et al., 1996; Shallice, 1982; Zelazo et al., 1997) stressed the importance of WM capacity as a core underlying mechanism involved in higher-order processes of planning and goal-directed behavior. Therefore, understanding WM is very important in understanding EF.

WM refers to a set of cognitive processes in retainment and manipulation of information required in the daily activities (Baddeley, 2003). In this regard, WM uses the processes of rehearsal, retrieval, manipulation, and controlled attention. Baddeley (1998a) stated that

> I would like to suggest that working memory is the system that, through an association with conscious awareness, allows the various channels representing objects in the world to be bound together as a unitary experience, which in turn allows the constituents of an episode to be bound in memory, facilitating subsequent recollection (p. 168).

According to this statement, the occupation of WM is binding different components of experience together with consciousness, so that it becomes more than a simple learning—it enables recollection through contextualization of that experience. Baddeley (1998a) argued that WM system needs two main processes in order to be optimally useful: (1) selective attention to the appropriate stimuli, and (2) being reflective, so that it can be evaluative about the appropriateness of the information. For this reason, WM refers to a limited capacity system that simultaneously supplies a temporary storage of current relevant information and processing of it for the appropriate use (Daneman & Carpenter, 1980).

Multiple Components Models of Working Memory

Baddeley and Hitch (1974, as cited in Baddeley, 1996) proposed the first multicomponent model of WM. Initially, their model involves a central executive and two slave systems (phonological loop and visuospatial sketchpad), but later they revised the model including the episodic buffer as the third slave system. In the initial model, two slave systems collect information from sensory modalities, and the central executive organizes the incoming information in order to use them in the goal-directed behavior. According to this model, phonological loop is involved in auditory processing and storage of verbal information in acoustic codes, whereas the visuospatial sketchpad has the same occupation for visual information through using different sub-systems for visual and spatial information (Baddeley, 1998a). After revision, the episodic buffer, the third slave system, is responsible for integration of previously learned information to the manipulation of environmental stimuli (Baddeley, 2000). Involvement of episodic buffer in the model is crucial because Baddeley (2003) claims that episodic buffer allows for the conscious awareness, which provides "a convenient binding and retrieval process" in the integration of different multi-modal information (p. 835). Different from the slave systems, the central executive involves the capacity for executive control of information coming from the slave systems (Baddeley, 1996). Baddeley and Wilson (1988, as cited in Baddeley, 1998b) argued that executive control is the control and use of information coming simultaneously from different parts of the brain.

Baddeley (2003) claims that although the central executive is the most essential part of the model, it is not clearly understood. He argued that there is a tendency to attribute all of the functions that are not related to the storage systems to the central executive. Hence, the central executive is mistakenly observed as a single system that makes decisions in an unclear way ("a single homunculus") (Baddeley & Logie, 1999). However, Baddeley (1996) defined the central executive as a unified system that uses multiple executive processes, which are dividing attention among different stimuli, selective attention to the appropriate stimuli, inhibition of inappropriate responses, and activation of previously stored information.

Cowan's Embedded Processes Model (1999) is also a multicomponent model of memory system. According to this model, memory system is composed of different activation levels, and three embedded components were defined with respect to the level of activation: (1) long-term store, (2) activated memory, which corresponds to short-term store, and (3) attention focus (Cowan, 1999). According to this model, currently active information in the activation memory is embedded in the long-term store, and retrieved from there through attention focus. In this regard, WM involves not only the information activated with attention focus, but also the inactive information in the long-term store. On the other hand, this model does not specify any slave systems like phonological loop or visuospatial sketchpad due to the fact that Cowan claimed that WM involves modality-specific codes (i.e., acoustic, visual, tactile, or semantic) and the embedded-processes are equally used in each of the modalities. To be more specific, short-term store involves visual codes, and when an image enters to this store, the attention focus activates the appropriate visual information in the long-term store in order to use it (or manipulate it through attention focus in order to be used) in the current task (Cowan, 1988).

The study of Oberauer, Wilhelm, and Witmann (2003) also supported the non-unitary nature of WM in their study. They explored the nature of WM via structural equational modeling of various WM tasks, and they found that WM is composed of three components: (1) simultaneous storage and processing, (2) supervision, and (3) coordination of information. The function of simultaneous storage and processing refers to the most common function of WM: it involves not only the concurrent storage of information, but also the processing (i.e., transformation of information). The second function of WM, the supervision, refers to the executive processes for self-monitoring, so that it involves use of representations of goals, flexible thinking and switching, and prevention from distraction. Finally, the coordination function is about relational integration since it is responsible for building new informational structures, i.e., mental structures for a cognitive task.

The Unitary Models of Working Memory

Just and Carpenter (1992) defined WM as a quantitative capacity rather than a system with multiple components. This conceptualization is in line with Daneman and Carpenter (1980) who suggested that WM is a capacity of simultaneous storage and processing, and developed the first complex span task, the Reading Span Task, measuring this capacity.

Just and Carpenter (1992) argued that WM is involved in reasoning and problem solving, especially in language comprehension since it requires processing a sequence of symbols perceived one at a time. According to them, WM is basically what Baddeley defines as central executive without having modality-specific slave systems. In other words, WM involves both storage and processing of information in a unitary single system. For instance, when you face with a “verb”, you simultaneously perceive it syntactically, semantically, and pragmatically. Considering these, Just and Carpenter (1992) define WM capacity as individual’s capacity to execute simultaneous processes.

Similarly, Engle, Tuholski, Laughlin, and Conway (1999) conceptualized WM with respect to individual’s capacity of controlled attention processes. In an empirical study, they found that WM and STM are distinct components of the memory system, but they are highly related (r = .68) because the WM is simply the STM capacity plus executive control processes (controlled attention). In this regard, Engle and colleagues (1999) suggested that WM capacity is mainly individual’s capacity of executive control processes. In addition, Kane and Engle (2002) stated that although WM involves domain-specific modalities (i.e., verbal, acoustic, semantic, or visual), how WM uses them is domain-free. Nevertheless, the domain-specific modalities are not defined as mediated with separate subsystems like phonological loop or visuospatial sketchpad. Therefore, WM refers to a domain-free capacity of controlled attention, which functions similarly in every code of domain, and this characteristic of WM differentiates it from the STM (Engle et al., 1999).

The distinction between STM and WM is observed in the assessment of these constructs. Hitch (2006) claims that STM and WM capacities cannot be differentiated and purified in a measure, but simple span tasks load more on the STM whereas complex span tasks benefit from the WM capacity. In this regard, it is argued that when the task forces an individual to use controlled attention processes, rather than simply asking for a storage capacity, it benefits more from the WM capacity (Conway et al., 2002; Engle et al., 1999). On the other hand, Engle and colleagues (1999) argued that some simple span tasks are used as a measure of WM capacity in children. For instance, Bull et al. (2008) differentiate forward digit-span and backward digit-span, and suggested that forward recall provides information about children's storage capacity (the STM capacity), whereas backward recall necessitates storage, maintenance, and the manipulation of information in memory, so that backward recall relies more on the WM capacity in children.

The Relationship among Executive Functions, Working Memory, and General Fluid Intelligence

Cattell introduced the terms fluid intelligence (*gf*) and the crystallized intelligence (*gc*) (1977, as cited in Jensen, 2002). Fluid intelligence refers to the reasoning ability we use in novel situations, whereas crystallized intelligence is about one's scholastic knowledge. Since the fluid intelligence refers to one's ability to solve complex novel problems through reasoning, nonverbal reasoning tests strongly benefit from the *gf* capacity of the individual (Jensen, 2002; Yuan, Steedle, Shavelson, Alonzo, & Oppezzo, 2006).

There are many studies in the literature considering the relationship between WM and *gf*. For instance, Kyllonen and Christal conducted an investigation of WM capacity and intelligence through a latent variable analysis (1990; as cited in Engle et al., 1999). They found that correlations between factors of WM and fluid intelligence range from .80 to .90. Hence, Kyllonen and Christal suggested that WM should be a necessary system for fluid intelligence (as cited in Engle et al., 1999).

Engle and colleagues (1999) also examined relationship among WM, STM, and fluid intelligence via latent variable analysis, and they found that the correlation between WM and fluid intelligence is .49 after controlling for the variance related to STM. In another study, Fry and Hale (1996) investigated the relationship among processing speed, WM, and fluid intelligence. They used Raven's Progressive Matrices as a *gf* measure, and four simple memory tasks, which are modified in order to assess WM capacity. Results indicate that there is a significant relationship between WM and fluid intelligence (r = .38) after controlling for variance related to age and processing speed. Likewise, Conway, Cowan, Bunting, Therriault, and Minkoff (2002) conducted a latent variable analysis in order to investigate the relationship among WM, STM, processing speed, and general fluid intelligence. Results indicated a strong relationship (r = .60) between WM capacity and fluid intelligence, whereas neither STM nor processing speed displayed a significant relationship with fluid intelligence.

Considering all, results of different studies investigating relationship between WM and fluid intelligence indicate that there is a statistically significant relationship between WM and fluid intelligence after controlling for the confounding variance. However, although it is consistently found that WM is a significant predictor of *gf*, two constructs cannot be considered as identical (Engle et al., 1999).

Several studies indicate that there are inter-related processes involved in WM and EF. For instance, Oberauer et al. (2003) indicated that WM is composed of three components, and the supervision component refers to the executive processes since it involves mental shifting. Additionally, several theoreticians (i.e., Barkley, 1997;

Pennington et al., 1996; Roberts & Pennington, 1996; Shallice, 1982) indicated the involvement of WM as a separate construct in executive functioning. Therefore, there should be an association between EF and fluid intelligence due to the fact that both EF and *gf* are related to the WM capacity of the individual.

There are some studies indicating significant correlations between EF and intelligence (i.e., Ardila, Pineda, & Rosselli, 2000; Arffa, Lovell, Podell, & Goldbergi 1998; Bielak, Mansueti, Strauss, & Dixon, 2006; Friedman, Miyake, Corley, Young, DeFries, & Hewitt, 2006). For instance, Friedman et al. (2006) explored the relationship between three EF domains (i.e., inhibiting, shifting, and updating tasks) and intelligence tasks. The Raven's Progressive Matrices and Block Design subtest of the WAIS were administered as *gf* measures; and Information subtest of the WAIS and a vocabulary test were administered as *gc* measures. The scores were subjected to a confirmatory factor analysis (CFA), and it is found that EF tasks were categorized under the factors of inhibition, updating, and shifting separately, and *gf* and *gc* tasks loaded on fluid and crystallized intelligence factors separately. What's more, the correlations among these factors revealed that the updating factor, which is more related to WM, is significantly correlated with fluid intelligence ($r = .74$) and crystallized intelligence ($r = .79$). Hence, the study of Friedman et al. (2006) indicated that there is a significant correlation between intelligence and the EF component that is mostly associated with WM capacity.

In another study, Bielak et al. (2006) investigated correlates of specific EF measures, the Hayling and Brixton Tests, in a sample of older adults. In addition to EF measures, a reasoning ability test (the Letter Series Test), and a crystallized intelligence test (multiple-choice vocabulary test) were administered. Correlations between EF and intelligence measures revealed that fluid intelligence contributes to performance on EF measures to some extent, whereas the contribution of the crystallized intelligence is very little.

There are also studies considering the relationship between specific EF scores and intelligence quotients. For instance, Arffa et al. (1998) investigated the relationship between WCST scores and full scale IQ obtained from the WISC-R in a group of 9- to 14-year-old children. Participants had above average or superior level IQs. As a result of multiple regression analyses, it is found that full-scale IQ scores significantly predict WCST scores of total errors, perseverative errors, nonperseverative errors, and trials to complete first category.

Additionally, Ardila et al. (2000) investigated the relationship between WCST scores, and the verbal and performance IQ scores obtained from the WISC-R in a group of adolescents aged 13-to-16 years. They found that the WCST score of perseverative errors is negatively correlated with verbal and full-scale IQ scores. Additionally, perseverative error score is separately correlated with WISC-R subtests of Information, Similarities, Arithmetic, and Block Design.

In sum, these studies suggest that there are significant correlations between EF measures (or specific EF scores) and intelligence measures (Ardila et al., 2000; Arffa et al., 1998; Bielak et al., 2006), and this relationship seems to be mediated by the association of WM and fluid intelligence (Friedman et al., 2006).

Assessment of Executive Functions

Executive functions are central in mechanisms involved in daily living, i.e., coping with novel situations, and management of academic and interpersonal skills (Baron, 2004). Assessing EF provides information about person's typical response patterns, such as how a person conducts an activity, rather than what the person knows and how much knowledge/skill is available in that person (Baron, 2004; Lezak, 1982). In this regard, assessment of EF provides more information than intelligence or achievement tests since it is basically the assessment of a process rather than checking for availability of a single entity (i.e., skill, knowledge etc.).

Since assessment of EF requires assessment of related skills and processes at the same time, there is a problem of low construct validity in EF measures (Miyake et al., 2002). For instance, some of the EF measures mainly assess the child's inhibition capacity (e.g. Stroop tasks, Go-No Go Tasks), some of them measure fluency (e.g. Verbal Fluency Tests, Design Fluency Test), and some of them mainly provide information about the child's estimation capacity (i.e., reasoning ability) (e.g. Biber Cognitive Estimation Tasks, Raven's Progressive Matrices) (Baron, 2004). On the other hand, there are EF tasks that measure more than one EF capacity, such as planning, organization, reasoning, and shifting (e.g. the WCST, Category Test, Tower of Hanoi, Tower of London, Brixton Spatial Rule Anticipation Test and Junior Brixton Test) (Baron, 2004; Shallice et al., 2002). Nevertheless, Miyake and colleagues (2002) argue that the problem of task impurity arises in these tasks since they involve not only the executive processes, but also the nonexecutive ones (i.e., motivation level, visual discrimination etc.). Therefore, a comprehensive assessment of EF necessitates the use of a neuropsychological battery rather than the use of only one EF measure. Additionally, investigating factorial structures of EF instruments, and their relationship with other cognitive tasks is essential for understanding the nature of EF, and further improvement of assessment utilities.

Majority of EF measures are developed for adult populations for diagnostic purposes, but some of them are also useful in detecting children's EF capacity

(Anderson, 2002). More recently, there is an increasing interest in validation of EF measures, and developmental norm studies of EF in children since EF impairment is central in most of the childhood disorders, such as ADHD, learning disability, autism, and conduct disorder (Baron, 2004; Griffith et al., 1999; Pennington et al., 1993). For example, the WCST is developed for adult populations, but it is also informative for children's EF skills (Shu, Tien, Lung, & Chang, 2000). In addition, Brixton Spatial Rule Attainment Test (BSRAT) is an adult-level EF measure, but it is recently adapted for 7-to12-year-olds in order to assess their EF skills (Shallice et al., 2002). These two tests, the WCST and the Junior Brixton Spatial Rule Attainment Test (JBSRAT), are the main EF tasks in the present study. Hence, they are separately and specifically described with respect to conceptual models and research-based evidence.

The Wisconsin Card Sorting Test (WCST)

The WCST is a widely used neuropsychological instrument developed by Berg in 1948 in order to obtain a quantitative measure for abstract thinking and mental set shifting (Berg, 1948; Heaton, 1981). Heaton (1981) provided the standard version of the test. Although the original WCST is developed for normal adult populations in order to assess the abstraction and problem-solving abilities, it can be applied to individuals aged 6 years, 6 months to 89 years (Heaton, 1981).

The original WCST has 60 response cards and 4 stimulus cards (Berg, 1948), but the Heaton version consists of 128 response cards and 4 stimulus cards, each of which has a combination of different forms in different colors and numbers (Heaton, 1981). The main purpose of the test is to match each response card to a stimulus card.

The test has correct sorting principles, but the individual is not informed about them. Rather, s/he should infer the rule through the use of feedback ("right" or "wrong"). The first principle is sorting with respect to color. After 10 consecutive correct matches, the sorting principle changes to form without any warning. Then, the sorting principles change as follows: number, color, form, and number. At the end, the WCST provides not only the scores for successful attempts of the individual, but also specifically stresses certain failures with certain scores (Heaton, 1981). For instance, the main focus of WCST is on the participants' perseveration tendency via considering the participants' ability to shift the response when necessary (Heaton, 1981). Additionally, it provides quantitative evaluation of other failures such as inefficient initial conceptualization, difficulty in consistent self-monitoring in order to maintain the conceptual rule, and inefficient learning throughout the test (Heaton, 1981).

Originally, the WCST is manually applied, but its computerized version is also available. Tien, Spevack, Jones, Pearlson, Schlaepfer, and Strauss (1996) compared the performances obtained from two versions of the test. They argued that in the computerized version there are more nonperseverative errors than in the manual version since the participants make rapid responses in the computerized version. However, it is found that the key parameters of the WCST (perseveration responses, perseveration errors, trials to complete the category, and percent of conceptual level response) are not affected by the administrative procedures of the test (Tien et al., 1996). Additionally, the computerized version of the WCST is argued to provide a more reliable measure of executive functioning since it decreases the effects of variability and errors in test administration (Tien et al., 1996).

Understanding the conceptual processing in the WCST is crucial in order to understand the possible strengths and weaknesses of the individual with respect to his/her executive functioning ability. First of all, in the WCST, individual can obtain the task relevant information from (1) the response card (test card), and (2) the feedback after his/her response, but it is the use of feedback that sustains problem-solving (Somsen, 2007). In other words, individual should continue on the rule s/he applied after the positive feedback, and should try a new strategy after a negative feedback in order to find out the correct sorting principle. In this regard, the use of feedback requires abstraction ability (Somsen, 2007). For instance, in the initial phase of the test, participant has no clue about the correct sorting principle, so that s/he makes a guess. In this phase, participant is assumed make an inherent decision strategy (i.e., red goes to red), which is the abstraction of a sorting rule from the features of the card. Then, the participant receives feedback. After the feedback, s/he should either continue on his/her initial strategy or shifts to another strategy. Since some of the responses may be ambiguous (i.e., it matches with respect to both color and number), a possible positive feedback refers to more than one rule. Hence, the positive feedback provides “ambiguous verification”, so that participant should further test whether his/her strategy is correct for the other consecutive trials and continue on the correct sorting rule after s/he is certain about it (response maintenance) (Somsen, 2007, p. 666). On the other hand, a negative feedback gives a more distinct message than the positive one since it means to the participant that the strategy you have in your mind is clearly wrong. In this regard, negative feedback is a “conclusive falsification” (Somsen, 2007, p. 666). Hence, it necessitates inhibition of the current hypothetical rule and shifting to the new one. Inherently, throughout this decision-making process, individual should benefit from capacity of abstraction, ability to maintain appropriate response, inhibition capacity, and shifting ability.

Somsen, van der Molen, Jennings, and van Beek (2000) indicated two phases in the WCST: (1) rule search and (2) rule application. The rule search phase involves hypothesis testing about the sorting principle, so that beneficial use of feedback, inhibition of the previous rules, and set shifting are crucial in this phase. In this phase, participant finds out the correct sorting principle. Secondly, in the rule application phase, individual should use simple action plans and mental operations, i.e., in the case of sorting with respect to color; other features of cards (form and number) should be disregarded (Somsen et al., 2000).

It is argued that performing WCST demands attention regulation, which is considered to play a significant role in executive functioning and WM capacity (Kane & Engle, 2002; Shallice, 1982; Shallice et al., 2002). With respect to the SAS model, Somsen and colleagues (2000) claimed that in performing the WCST, rule application process can sufficiently benefit from the contention scheduling process alone since it involves the maintenance of previously held schema automatically (i.e., sorting with respect to color). On the other hand, rule search phase demands the involvement of SAS because of the fact that rule search requires the dynamic orchestration of attentional processes and cognitive abilities in order to formulate an adaptive solution for the presented novelty (i.e., finding out the initial sorting principle).

The WCST has been widely used in research. Some studies investigated the internal structure of the WCST, and these studies are generally conducted in the adult populations. Additionally, the WCST is used in studies with children, such as developmental norm studies, and investigations of the sensitivity and specificity of the WCST in typical developing children and clinical samples of children were of focus.

Factorial Structure of the WCST

There are numerous studies investigating the factorial structure of the WCST, and the study of Sullivan et al. (1993) was one of the earliest of them. In their study, Sullivan and colleagues (1993) explored the factor analytic structure of the WCST in a sample of patients with schizophrenia and people with chronic alcoholism. In addition to the Heaton version scores, they made some other calculations, such as unique errors, and total correct minus corrects achieved in successful categories. There were 22 male participants who met the diagnostic criteria in Diagnostic and Statistical Manual of Mental Disorders, third edition, revised (DSM-III-R) for schizophrenia, 20 male participants who met criteria for alcoholism, and 16 community volunteers (males) as the control group. The Heaton version WCST is applied, but the test continued until all of the 128 cards were used even if the participant successfully completed 6 categories. Additionally, they applied a WM measure (i.e., Verbal Self-Ordering Test) and other tests of memory function (i.e., recognition of nonverbal material, delayed recall of verbal memory etc.). As a result, three factors explained the 91% of the total variance in WCST performances: (1) perseveration factor (total errors, perseverative responses, perseverative errors, total correct responses, conceptual level responses, and categories completed), (2) inefficient sorting factor (failure to maintain set, and total correct minus corrects achieved in successful categories), and (3) nonperseverative errors factor (nonperseverative errors and unique errors). There was a high correlation among three factors in the control group, and a moderate correlation was observed in the patient groups. Furthermore, Sullivan and colleagues (1993) claimed that perseveration factor was found to be a valid measure of the frontal-lobe dysfunction in schizophrenia, but not in alcoholism.

Koren et al. (1998) also investigated the factor structure of the WCST in a sample of patients with schizophrenia. There were 243 patients who had a diagnosis of schizophrenia, 39 patients with schizoaffective disorder diagnosis, and 10 patients with schizophreniform disorder diagnosis. Moreover, 91 individuals who had a first-degree relative with schizophrenia, and 141 controls were participated in the study. The Heaton version WCST was administered. Except for the nonperseverative errors (NPE) score, the Heaton version scores were used in analyses. Additionally, two new scores, which are unique errors and failure to maintain set after 3 correct trials, were calculated. Results revealed a three-factor solution explaining the 88.45% of the total variance: (1) perseveration (total errors, perseverative errors, perseverative responses, total correct, trials to complete first category, and categories completed), (2) failure to maintain set (FMS after 5 correct trials, and FMS after 3 correct trials), and (3) idiosyncratic sorting (unique errors). However, correlations among three factors did not yield statistical significance. Since the NPE score was omitted in this study, the third factor came up as “idiosyncratic sorting”.

In another study, Greve, Ingram, and Bianchini (1998) conducted two extensive investigations on the factorial structure of the WCST. First of all, they analyzed data of 10 factor analyses of the WCST in four different studies. Salient variables (*s*) and coefficients of congruence (*c*) were calculated for all of the factor analyses reported in those papers in order to find out whether or not the indicated factors were consistent. They found that the perseveration factor (Factor I) displayed a highly similar pattern across studies, except for one study. This factor consistently had loadings from percent conceptual level responses (%CLR), categories completed (CC), perseverative errors (PE), perseverative responses (PR), total errors (TE), and total corrects (TC). Factor II was also consistent across studies, having salient loadings from failure to maintain set (FMS), and TC scores. On the other hand, nonperseverative errors (NPE) loaded on Factor II inconsistently. The pattern of Factor III was not explored in this study due to lack of consistent data across studies.

In addition, Greve and colleagues (1998) explored the latent structure of the WCST in a separate experiment. Data was obtained from the neuropsychological evaluation files of 473 patients from different centers (e.g. rehabilitation centers, and outpatient neuropsychology clinics). Patients' data was included in the study if they both completed the WCST and the Wechsler Adult Intelligence Scale-Revised (WAIS-R). Principle component analysis with an orthogonal rotation was used in the study. Results revealed a three-factor solution, explaining 94% of the variance. Moreover, split-half analysis was also conducted to explore the stability of the factor structure, and internal consistency was established since factor structures in both halves were found identical. Factor I had loadings from TC, PE, PR, CLR, and CC. Different from previous research, Factor II had loadings from NPE score rather than FMS. Moreover, FMS score loaded on the Factor III. In addition, they further examined the factorial structure within each diagnostic group (brain trauma, stroke, dementia, and psychiatric), and they found the three-factor solution consistently in each group, explaining 95.3%, 95.0%, 96.6%, and 91.3% of the total variance, respectively.

In another study, Greve and colleagues (2002) investigated the factorial structure of the WCST in a sample of 68 patients with traumatic brain injury (TBI), whose ages ranged from 18 to 58. The WCST is administered manually in standard fashion. Differently, test continued until all of the 128 cards were used although the participant achieved 6 categories. Seven scores of the WCST were used in analyses: total correct (TC), perseverative responses (PR), perseverative errors (PE), nonperseverative errors (NPE), percent conceptual level response (%CLR), categories completed (CC), and failure to maintain set (FMS). They replicated the three-factor solution: (1) cognitive flexibility factor (Total Correct, %CLR, PE, PR, and CC), (2) problem-solving factor (NPE), and (3) response maintenance factor (FMS).

Greve, Stickle, Love, Bianchini, and Stanford (2005) also investigated the internal structure of the WCST. Differently, they applied confirmatory factor analysis in a large sample of neurological and psychiatric patients, and non-clinical controls, aged 15 to 90 years (*N*= 1221). Similar to the study of Greve et al. (2002), they used seven scores of the WCST. Results indicated three models, and only the one-factor and the three-factor models yielded statistical significance (CFI > .95): (1) Factor I had loadings from PE, PR, CLR, CC, and total corrects; (2) Factor II had loadings from CLR, CC, total corrects, and NPE; and (3) Factor III had loadings from total corrects, and FMS. Nevertheless, only the first factor, named general executive function, was statistically meaningful while the second and third factors (problem-solving and distractibility) were explanatory only if all of the 128 cards were used in the test. Consequently, Greve and colleagues (2005) argued that there is a significant overlap among variables so that none of the models displayed a true fit to the observed data. Additionally, the effect of different diagnostic groups, and participants’ age and education level might have interfered with results.

Different from the studies mentioned above, Lee, Riccio, and Hynd (2004) investigated the factorial structure of the WCST and WM measures in a sample of 8-

to 12-year-old children. They aimed to explore the role of EF in ADHD, so that they administered various cognitive tasks (i.e., WCST, Verbal Fluency Task, WISC-III subtests of Digit Span, Arithmetic and Coding, Hand Movements from the Kaufman Assessment Battery for Children, and Oral Directions from the Clinical Evaluation of Language Fundamentals). All of the measures were subjected to a principal component analysis with an oblique rotation, and a three-factor solution was revealed: (1) the executive concept formation factor had loading from the WCST scores of NPE, CLR, and CC; (2) WM factor had loadings from all of the measures except WCST scores, and (3) cognitive perseveration factor involves WCST scores of perseverative response and perseverative errors. Hence, rather than a one-factor solution for the WCST, test scores were categorized into two main factors: concept formation and perseveration.

Likewise, Yeniçeri and Altan-Atalay (2008) explored the factorial structure of the WCST in 8-to 11-year-old children. Four hundred and forty eight students from elementary schools in Istanbul were enrolled in this study, and data was investigated through explanatory factor analysis (EFA). Results revealed a three-factor solution, explaining 90.34% of the total variance: (1) conceptual thinking factor (TC, NPE, CLR, and %CLR), (2) perseveration factor (PR, PE, and %PE), and (3) set maintenance (FMS). This model is different from the three-factor models observed in the adult populations since the perseveration scores and the conceptual understanding scores (i.e., CLR) loaded on different factors. Additionally, NPE did not emerge as a single factor, but loaded on the conceptual thinking factor (Factor I).

Considering all, factorial studies of the WCST consistently reveal a three-factor solution rather than a one-factor solution. In studies with adult samples, the first factor (perseveration or cognitive flexibility) seems salient across studies since it generally has loadings from PE, PR, CLR or %CLR, CC, and TC scores. However, the second and third factors may differ such that in some studies FMS is the second factor and the NPE is the third factor, whereas in others it is the vice versa. On the other hand, in studies of Yeniçeri and Altan-Atalay (2008) and Lee and colleagues (2004), the factorial structure of the WCST in children is different from the three-factor solution observed in adult samples since concept formation scores (i.e., CLR and CC) and the perseveration scores (i.e., PR and PE) loaded on different factors.

Other WCST Studies with Children

In addition to the studies of Yeniçeri and Altan-Atalay (2008) and Lee et al. (2004), there are other studies of the WCST with samples of children. There is a growing interest in understanding the developmental trends in executive functions, especially for the assessment procedures of EF (Welsh & Pennington, 1988). Hence, some studies with children are developmental norm studies of the WCST, and Chelune and Baer (1986) conducted one of the oldest of them. They applied the WCST and the Peabody Picture Vocabulary Test (PPVT) to 105 school-age children from grade 1 to 6. The Heaton version scores were used in the analyses, except that FMS score was calculated with respect to two response patterns: (1) FMS after 5 consecutive correct responses (similar to Heaton version FMS score), and (2) FMS after 3 consecutive unambiguous correct responses. Comparisons were held with respect to gender and age, and they found that there is a developmental increase as a function of age in CC, FMS, and perseveration scores. Additionally, Chelune and Baer (1986) compared the performances of children in their study with adult norms indicated in the manual of Heaton. They found that (1) the mean performance in CC scores of children reached the adult level performances by the age of 9, and (2) the mean scores of PE and FMS were similar to adult level performances by the age of 10. They indicated that children display perseveration tendency at the age of 6 as it is observed in their WCST performances.

Similarly, Shu et al. (2000) aimed to establish the developmental norms for the WCST in 6- to 11-year-old children in Taiwan. Additionally, they examined the effect of age, gender, birth order, number of siblings, and education level of parents on the WCST performances of children. Then, they compared the results with norms for children in the USA. Participants were 219 students of grade 1 to 6. Computerized WCST was administered, and the demographic data were obtained. Results indicated that the difference between performances of males and females was not statistically significant. On the other hand, the effect of age on the WCST performances was profound. For instance, as the age increased, mean scores of TC, CC, and percent CLR increased, and the mean scores of PE, PR, and NPE decreased. These results are in line with the study of Chelune and Baer (1986), indicating that after 6 years of age children display rapid growth in the WCST performances. This pattern of change with age was also found to be similar to the data of children in the USA, but mean scores for the number of achieved categories were lower in the Taiwan sample than in the USA sample. Furthermore, in the USA sample, the mean score of PE was similar to the adults', whereas in the Taiwan sample, the mean score of PE was still higher (M = 17.51) compared to the adults.

In another study, Bujorenau and Willis (2008) compared the WCST performances of children in different age groups. They further investigated the conceptual difficulty of the WCST in younger children through manipulating the order of sorting categories of the task. Previous studies argued that number category may remain a more abstract category for younger children in comparison to color and form categories because of the fact that younger children still have computational difficulty and poor numerical concept formation at that developmental level (as cited in Bujoreanu & Willis, 2008). In this regard, they examined not only the age-related differences in the WCST performance, but also the effect of the order of number category on the WCST performances of children. In their study, there were 196 participants, who were categorized into three age groups: 6-year-olds, 11-to 12-year-olds, and 18-to19-year-olds. The study was operationalized in a 3x3 factorial design with respect to three age groups and the serial position of the number category. The WCST was administered according to Heaton's manual, and dependent variables were categories completed, learning to learn, and percent total errors scores of the WCST. Results are in line with the developmental norm studies: WCST performance differs as a function of age. For example, 6-year-olds completed fewer categories, and displayed poorer learning efficiency than 11-12-year-olds and 18-19-year-olds. Moreover, 6-year-olds made more errors than older groups did. Additionally, they found that the order of number criterion had a significant effect on the WCST performances in relation with age. For instance, 6-year-olds completed fewer categories when the number was the first criterion than when the number was the third criterion, whereas CC scores of the older age groups were not affected by the order of sorting criteria. Additionally, older age groups made fewer errors when the number was the first criterion than when number was the third criterion. Thus, Bujoreanu and Willis (2008) claimed that number is the most difficult sorting principle in comparison to color and shape for the 6-year-olds' developmental level. In this regard, they argued that the WCST can validly measure the set-shifting ability in 11-12-year-olds and 18-19-year-olds, but in the youngest age group, inclusion of the number criterion makes the task a measure of numerical ability of children. Therefore, they suggested that the validity of the WCST in the 6-year-olds should be explored in further studies.

Furthermore, questions of what specifically the WCST measures and whether or not the WCST validly and reliably discriminates specific clinical groups are the objects of various studies in the literature. In this regard, Romine et al. (2004) conducted a meta-analysis of research on the WCST in order to investigate the sensitivity (i.e., discriminating a specific clinical group from the non-clinical group) and specificity (i.e., discriminating a specific clinical group from other clinical groups) of the WCST scores in children. They analyzed the results of 32 journal articles and 1 dissertation published in years from 1984 to 2002. Within each study, Romine and colleagues (2004) calculated Cohen's d values for each WCST variable in order to obtain the effect size of each. As a result, the WCST was found as a sensitive measure in discriminating ADHD group and typically developing children (e.g. Percent TC, TE, CC, and PE displayed medium effect sizes, and PR had a close-to-medium effect size), whereas impairment on the WCST was not found to be specific to the ADHD since children with learning disability (LD) performed poorer than the ADHD group on the WCST. Additionally, they suggested that although both children with LD and typically developing children displayed a similar developmental pattern on the WCST performances, the performance of children with LD at a certain age period is below the performances of normal peers. Romine and colleagues (2004) also compared the WCST performances of children with conduct disorder, anxiety and mood disorder, autism spectrum disorders, and psychotic disorders. As a result, they found that although the WCST has sensitivity to frontal lobe dysfunction, poor performance on the WCST does not indicate any specific diagnosis (i.e., ADHD). Rather, poor WCST performance may indicate an underlying neurological disorder that should be explored in further assessment.

Additionally, Yeniad (2009) examined the WCST performances of 6- to 7-year-old children. Eighty-nine children whose ages ranged from 6.2 to 7.7 participated in the study. Participants were administered the Heaton version of computerized WCST as an EF measure, backward digit-span (BDS) subtest of Wechsler Intelligence Test for Children-Revised (WISC-R) as a verbal WM measure, the finger windows (FW) subtest of the Wide Range Assessment of Memory and Learning (WRAML) as a visuospatial WM measure, and the nonverbal battery of the Cognitive Abilities Test (CogAT®) as a fluid intelligence measure. Results revealed that specific WCST scores (i.e., TC, TE, CLR, CC, and trials to complete first category) correlated significantly with BDS, FW, and the nonverbal CogAT® scores. Hence, Yeniad (2009) argued that most of the WCST scores are associated with WM capacity of children. However, perseveration scores did not significantly correlate with measures of WM or fluid intelligence, indicating that what is specifically measured in the WCST is the tendency to perseverate.

The Junior Brixton Spatial Rule Attainment Test (JBSRAT)

Junior Brixton Spatial Rule Attainment Test is the child-version of the Brixton Test (Brixton Spatial Rule Attainment Test), which was developed by Burgess and Shallice (1996b, 1997, as cited in Shallice et al., 2002). The Brixton Test is a rule-attainment task, in which concept formation and set-shifting abilities are crucial (Burgess & Shallice, 1996; Drake & Lewis 2003; Wood & Liossi, 2007), and the

Junior Brixton Test is a modified version for 7-to12-year-old children (Shallice et al., 2002).

Concept achievement is the crucial aspect of tasks involved in the assessment of patients with frontal impairment (i.e., the WCST), and the fundamental frontal behavior is often found to be perseveration in those tasks (Burgess & Shallice, 1996). On the other hand, Burgess and Shallice (1996) argued that the tendency to perseverate does not fully explain the behaviors of frontal patients in the concept formation tasks. For instance, Miller defined “cognitive risk-taking” behaviors, referring to impulsivity (as cited in Burgess & Shallice, 1996, p. 242). In this regard, Burgess and Shallice (1996) claimed that although the WCST is a sensitive measure of perseveration, it is not sufficient in detecting those risk-taking, impulsive behaviors (i.e., inappropriate guessing responses). Hence, they introduced an alternative test, the Brixton Test, providing a quantitative measure of both perseveration and inefficient guessing responses.

The Brixton Test is conceptually derived from the WCST. It is composed of 56 A4 pages, including 2x5 array of circles in each. One of the circles is filled while the remaining ones are plain. Across pages, the position of the filled circle changes with respect to certain rules that are designed in an unsystematic manner, and the participant anticipates the position of the filled circle in the following page without any information. Hence, participant should abstract each rule with respect to the relationship among consecutive trials. In this regard, the Brixton Test and the WCST are conceptually related EF measures. On the other hand, Burgess and Shallice (1996) argued that WCST differs from the Brixton Test since the rules of the WCST rely on perceptually salient aspects, which are color, number, and form. In other words, the WCST uses previously known features, so that “the relevant schemas are directly triggerable by second order representations of the input" (Burgess & Shallice, 1996, p. 255). Differently, in the Brixton Test, rules depend on the relationship between pages. In this regard, Burgess and Shallice (1996) argued that the concept formation in the Brixton Test is a more abstract process than in the WCST. Furthermore, Reverberi, Lavaroni, Gigli, Skrap, and Shallice (2005) argued that the more abstract rules in the Brixton Test put greater demand on participants' inductive reasoning capacity, which is impaired in the frontal patients.

Shallice and colleagues (2002) aimed to provide the child-version of the Brixton Test for the EF assessment of 7- to12-year-old children. In this regard, they modified the rules and pages, and introduced the JBSRAT. This test consists of 45 A4 pages, and each page contains 2x5 array of 10 turtles (9 gray turtles and 1 green turtle). In this case, the spatial position of the green turtle changes across pages with respect to five different rules: increasing by 1, decreasing by 1, switching between 5 and 10, staying on 9, and switching between 4 and 10. Different from the WCST, rule change does not require a certain number of consecutive correct responses, but occurs after each 9 pages. In this regard, Shallice and colleagues (2002) argued that rules of the JBSRAT are resistant to over-learning dues to the fact that rule changes after a specific number of trials, rather than achievement of certain successful responses. Hence, participants are not reinforced to use a previously held successful behavior, but they are required to abstract a totally new rule with respect to the relationship among cards.

Shallice and colleagues (2002) stated that the Junior Brixton Test provides three specific error scores. The first one is perseveration errors. Perseveration is coded when (a) the participant's response is in agreement with the previous rule (the rule of previous block of 9 trials), (b) the participant incorrectly gives the same response (i.e., repeatedly choosing the second turtle), and (c) the participant incorrectly points to the green turtle seen on the presented stimulus card (when the rule is not “to stay in the same place”). The second error score in the JBSRAT is plausible errors, and it refers to the incorrect nonperseverative responses that involve a figured-out spatial rule (i.e., pointing to a turtle spatially close to the stimulus turtle). Hence, plausible errors are considered as logical errors since they have a spatial relationship with the stimulus. Finally, third type of error is guessing errors, which refers to incorrectly pointing to places that are not spatially related to the green turtle. Shallice and colleagues (2002) suggested that guessing errors are illogical responses since the participant chooses a position that is irrelevant to the stimulus turtle. Hence, guessing error is considered as a measure of impulsivity (the risk-taking behavior), and it is argued that this kind of behavior is not relevant to the typical normal behavior in this type of situation (Burgess & Shallice, 1996; Shallice et al., 2002). In this regard, the Junior Brixton Test is an important EF measure providing the assessment of other frontal behaviors (i.e., guessing errors) in addition to perseveration.

Studies with the JBSRAT and the Adult-Version Brixton Test

Since the Junior Brixton Test is a recently developed measure, there is yet no study on it other than the study of Shallice et al. (2002). Their study investigated the EF difficulty in children with ADHD with respect to their performances in different neuropsychological measures (i.e., a sustained attention reaction time task, a vigilance task, a Letter Fluency task, a number Stroop task, and an n-back WM task). Additionally, they adapted the Hayling Sentence Completion Test and the Brixton

Spatial Rule Attainment Test to 7-to12-year-old children and used them in this study. Participants were 31 children with ADHD and 33 typically developing children, whose ages ranged from 7 to12 years. They categorized participants into two age groups: 7- to 8-year-olds and 9- to 12-year-olds. Results of the study revealed that ADHD group displayed poorer performance than control group on the JBSRAT scores of total correct, perseveration, and guessing response. What is more, it was also found that younger children made less total correct responses, and more guessing responses in comparison to the older age group. Neither age groups, nor clinical groups differed on their plausible responses. Considering these, Shallice et al. (2002) claimed that the JBSRAT is a sensitive EF measure that can distinguish children with ADHD and controls with respect to perseveration and guessing errors.

In another study, Bayliss and Roodenrys (2000) applied the adult-version Brixton Test to a group of 8-to-12 year-old children. In this study, Bayliss and Roodenrys (2002) aimed to investigate the Norman and Shallice's concept of SAS in children with ADHD through administering the Star Counting Test, the Hayling Sentence Completion Test, the Random Generation Test, and the Brixton Test. There were 15 children with ADHD, 12 children with LD, and 15 control children in the study. Regarding the Brixton Test performances, the mean differences of total number of errors among three groups were not statistically significant. Therefore, Bayliss and Roodenrys (2000) concluded that Brixton Test did not discriminate children with ADHD, children with LD, and typically developing children. Nevertheless, authors suggested that poor statistical power due to the small sample size might lead to this nonsignificant result ($p = .21$). In other words, children with ADHD might have difficulty on the Brixton Test, but the group differences on error were too small to yield a significance level in this sample size. Additionally, one should also consider that the Brixton Test was originally developed for adult samples, but it was administered to a group of 8-12-year-old children in that study. Hence, the small differences among groups might be related to the fact that all of the children, regardless of the clinical group, had difficulty on the task because of their age.

Other studies using the Brixton Test are conducted with clinical or non-clinical adult samples. Those studies are crucial in understanding the validity of the Brixton Test. For instance, some of them are factorial studies that aim to define specific components of different EF measures, and some of them directly investigate behavioral patterns of certain clinical patients (i.e., patients with schizophrenia and alcoholism) in different EF measures.

To begin with the factorial studies, Drake and Lewis (2003) investigated the relationship between insight and perseveration tendency in patients with schizophrenia with respect to their performances in six scales for insight, and several neuropsychological tasks including the Brixton Test. There were 33 patients diagnosed for schizophrenia, schizoaffective disorder, or delusional disorder, and their age ranged from 18 to 65. The measures of set manipulation (the Hayling B, the Trail Making B test, and the Brixton test) were subjected to Principal Component Analysis (PCA), and there found a two-factor solution: (1) The Hayling scores, and (2) total errors score of the Brixton Test, and time and error scores of the Trail B. The conceptual difference between these two factors was explained such that the Hayling Test is predominantly a measure of set suppression, whereas the Brixton and the Trail B tests measure set shifting. Hence, another PCA was performed with only the Brixton and Trail B scores, and a single set-shifting factor was found, explaining the 61% of the variance. Consequently, it would be claimed that the Brixton Test is a valid measure of set shifting ability.

In another study, De Frias, Dixon, and Strauss (2006) investigated the factorial structure of four EF measures (i.e., the Hayling Test, the Brixton Test, Stroop test, and the Color Trails test). Participants of the study were 427 adults from the sample of Victoria Longitudinal Study (VLS), which is an ongoing study on adult development. Mean age of the participants was 68.44 years, and the average education level was 15.23 years. In addition to four EF measures, the Letter Series and Vocabulary tests were administered as a measure of reasoning ability and crystallized intelligence, respectively. Confirmatory factor analysis result indicated that all of the four EF measures are organized under a single factor, indicating that Brixton Test and the other EF measures of the study share a conceptual commonality at the construct level (De Frias et al., 2006).

Additionally, Van den Berg, Nys, Brands, Ruis, van Zandvoort, and Kessels (2009) investigated the validity of the Brixton Test in a sample of patients groups. Participants were 283 healthy individuals and 656 patients (106 patients with stroke, 376 patients with diabetes mellitus, 70 patients with early dementia, 63 psychiatric patients, and 41 patients with Korsakoff's syndrome). In addition to Brixton Spatial Rule Attainment Test (BSRAT), the Rey Auditory Verbal Learning Test (RAVLT), Trail Making Test (TMT), and the Dutch version of the National Adult Reading Test (NART) were administered. Participants' scores were subjected to the Principal Axis Factoring (PAF) with direct oblimin, and two-factor solution explaining 60% of the variance was observed. The first factor is called verbal memory factor, which had loadings from the RAVLT and TMT A. The second factor was named mental flexibility factor, having loadings from TMT ratio score and the Brixton score.

Therefore, the Brixton error score is found to be more related with another EF measure rather than memory or speed. In this regard, authors claimed that this solution provides a convergent validity for the Brixton Test.

Other studies with patient groups mainly found that specific patient groups (i.e., schizophrenics, and alcoholics) displayed poorer performance on the Brixton Test in comparison to healthy individuals. For instance, Marczewski, Van der Linden, and Lari (2001) investigated the SAS functions (i.e., planning, inhibition, and rule abstraction) in a sample of patients with schizophrenia through administering three SAS tasks, which are Tower of London task, and the Hayling and Brixton Tests. Participants were 15 patients with schizophrenia with a mean age of 29.93 and a mean education level of 10.60 years, and 15 normal individuals who are matched to the patient group with respect to age, gender, and education level. On the Brixton Test, patient group did significantly more errors than the control group did. However, when each error type (i.e., perseveration, plausible, or guessing errors) was analyzed separately, the mean differences between groups did not yield a statistical significance for any of the error type. Hence, authors argued that although patients with schizophrenia displayed poorer performance on detecting simple rules and using them appropriately, there is not a qualitative difference between patients and normal individuals regarding the different error types. This result was inconsistent with the previous study of Sullivan and colleagues (1993), in which patients with schizophrenia made more perseveration errors than controls on the WCST. In this regard, Marczewski and colleagues (2001) argued that the main problem of patients with schizophrenia on the Brixton Test would be their impairment in rule abstraction.

Furthermore, Noel et al. (2001) investigated the frontal lobe functioning of alcoholic patients. Participants were 30 alcoholic males and 30 controls, and they were administered the Hayling Sentence Completion Test, the Brixton Test, verbal fluency tasks, Stroop test, flexibility test, and the Trail Making Test. On the Brixton Test, alcoholic patients made more errors than normal controls did. Plus, with respect to the error types, the alcoholic patients made more guessing errors than controls although two groups did not differ on perseveration errors. In this regard, authors argued that alcoholic patients behaved similar to the frontal patients regarding the guessing responses.

Finally, there are studies providing evidence for a significant relationship between the Brixton Test and intelligence (Bielak et al., 2006; Wood & Liossi, 2007). For instance, Bielak and colleagues (2006) investigated norms and correlates of the Hayling and Brixton Tests in a sample of 457 healthy adults, aged 53 to 90 years. In addition to Hayling and Brixton Tests, which are EF tools for children, they administered measures of fluid and crystallized intelligence to participants. Correlations among EF measures and intelligence tests indicated that fluid intelligence partly contributes to performance on EF measures while the crystallized intelligence test made a little contribution. Additionally, Wood and Liossi (2007) investigated the relationship between general intellectual ability and executive functions in a sample of patients with brain injury via using a group of intelligence and EF measures (i.e., WAIS-III, Hayling and Brixton tests, TMT, Zoo Map and Key Search subtests of the Behavioral Assessment of the Dysexecutive Syndrome battery). The findings of the study suggested that the performance on the Brixton Test is significantly related to the general intelligence ability.

Current Study

This study aimed to explore the validity of the JBSRAT with respect to comparisons with the WCST, BDS, and nonverbal CogAT®. The JBSRAT is the child-version of Brixton Test, which is conceptually derived from the WCST. Since conceptual roots of two tests are similar, the internal structure of the JBSRAT was expected to be similar to the internal structure of the WCST. In this regard, the factorial structures of two tests were examined via separate Principal Component Analyses (PCA) with varimax rotations in order to explore whether or not these two tests consist of similar factors. Moreover, the relationship between corresponding factors in each test was investigated through correlation coefficients among scores of WCST and JBSRAT.

The second aim of the present study was to explore the relationship among EF, WM, and *gf*. It is a fact that WM is a fundamental construct in executive functioning. For instance, some theoreticians stressed the importance of WM in cognitive flexibility domain of EF (Lezak, 1982); in prolongation (Barkley, 1997); in problem solving (Zelazo et al., 1997); and in SAS (Shallice, 1982). Therefore, it was expected that the JBSRAT and the WCST scores were significantly correlated with the BDS, which measures WM capacity in children (Engle et al., 1999). In addition, previous research suggested that fluid intelligence is significantly associated with WM (Conway et al., 2002; Engle et al., 1999; Fry & Hale, 1996). In addition, Friedman and colleagues (2006) found that the updating domain of EF, which refers to WM, is significantly related to the reasoning ability. That is why, it was expected in the present study that the BDS performances of children would be significantly associated with their performances on the nonverbal CogAT®, which is a valid and reliable measure of nonverbal reasoning ability in children (Alp & Diri, 2003). It was further expected that there would be significant correlations between EF measures and the nonverbal CogAT® since previous research suggests significant association of EF performance and intelligence (Ardila et al., 2000; Arffa et al., 1998; Bielak et al., 2006; Friedman et al., 2006).

The final aim of the study was to explore the effects of specific demographic variables (i.e., age, gender, grade, type of school, and maternal education) on the JBSRAT and the WCST performances. It is indicated in most of the previous research that children's performances on the WCST increase with age, and they achieve an adult-level performance at around 10 to 11 years of age (Ardila, Rosselli, Matute, & Guajardo, 2005; Bujoreanu & Willis, 2008; Chelune & Baer, 1986; Huizinga & van der Molen, 2007; Shu et al., 2000). In addition, some studies indicate that parental education level and the WCST performances are significantly associated (Ardila et al., 2005; Yeniçeri & Altan-Atalay, 2008). In this regard, present study expected that there would be a significant effect of age and maternal education on children's EF performances, such that their EF performances would increase as (1) the age of the participant increases, and (2) parental education level increases. On the other hand, it was not expected to find a gender difference since previous studies did not indicate a difference between males and females' WCST performances (Ardila et al., 2005; Shu et al., 2000; Yeniçeri & Altan-Atalay, 2008; Yeniad, 2009). Furthermore, this study investigated the effects of grade (i.e., first and second grade) and the type of school (i.e., private or public school) on children's EF performances.

CHAPTER 2

METHOD

Sample

One hundred and twenty five Turkish students from 3 public schools and a private school in Istanbul participated in the present study. Four participants were excluded from the study due to a suspicion of a neuropsychological disorder (i.e., possibility of language deficits, developmental delay, and very poor intellectual capacity). Hence, data of 121 participants (65 girls, 56 boys) were used in the analyses. Additionally, 58 of them were first grade students, and 63 of them were in grade 2. The participants' ages ranged from 6.0 and 8.11. As reported by their parents, none of the participants had any diagnosis of a psychological or neurological disorder. One hundred and six of the participants were right-handed, whereas 15 of them were left-handed.

Instruments

Demographic Information Form (DIF)

A Demographic Information Form (DIF) was prepared for this study. Participants' birth date, number of siblings and birth order, preschool education history, current medical condition, and parental educational level and occupation were asked in this form.

Wisconsin Card Sorting Test (WCST)

The WCST measures abstract thinking and mental set shifting (Berg, 1948). Heaton (1981) provided the standard administration of the test. The Heaton version computerized WCST was used in this study.

The WCST consists of 4 stimulus cards and 128 response cards. Four stimulus cards display “one red triangle”, “two green stars”, “three yellow crosses”, and “four blue circles”, respectively. The remaining response cards vary with respect to form (cross, circle, star, or triangle), number (one, two, three, or four) and color (red, green, blue, or yellow). The four stimulus cards are presented in the upper center of the 17-inched computer screen throughout the test, and response cards are displayed under the stimulus cards one by one after each response. The participant is asked to match each response card with one of the stimulus cards without any information about the sorting rule. Afterwards, the examiner tells the participant either right or wrong as a feedback about the response. There are 6 sorting categories in the test (i.e., color, form, number, color, form, and number). After 10 consecutive correct responses, the sorting category changes without any warning. Test ends either when the participant completes 6 categories or when all of the 128 response cards are used.

The WCST provides fifteen scores: trials administered (TA), total number of errors (TE), percent of total number of errors (%TE), total number of correct responses (TC), number of categories completed (CC), perseverative responses (PR), perseverative errors (PE), percent of perseverative errors (%PE), nonperseverative errors (NPE), percent of nonperseverative errors (%NPE), trials to complete the first category, number of conceptual level responses (CLR), percent of conceptual level responses (%CLR), failure to maintain set (FMS), and learning to learn.

The PR is coded (1) when participant makes an unambiguous incorrect match (i.e., “number”) in the initial category and continue to sort cards with respect to that principle (“number”); and (2) when the participant responds with respect to the sorting principle of the previous category after successfully completing it, such as sorting with respect to color in the second category, which is form. Some responses are ambiguous (i.e., match with respect to more than one category), so that some of the perseverative responses can be correct responses. In this regard, perseverative errors are incorrect perseverative responses.

Additionally, trials to make the first category refer to the total number of responses made until successfully completing the initial category. It is the measure of initial conceptualization before the rule-switch. Number of consecutive correct responses in runs of three or more is the CLR score. When the participant fails after making 5 consecutive correct responses, it is coded as a FMS score. The CC score indicates number of categories completed throughout the test. Finally, the learning to learn score is calculated only for participants who complete at least three categories, and it indicates “the patient’s average change in efficiency across the successive stages of WCST” (Heaton, 1981, p. 24).

Reliability

Ingram, Greve, Fishel Ingram, and Soukup (1999) examined the test-retest reliability of the WCST in a sample of patients with untreated obstructive sleep apnea (OSA). The Spearman Rho values of the test-retest correlations are .78 for trials administered, .34 for total correct responses, .79 for total errors, .79 for perseverative responses, .83 for perseverative errors, .80 for nonperseverative errors, .45 for conceptual level responses, .70 for categories completed, .44 for trials-to-complete-the first category, .50 for failure-to-maintain-set, and .61 for learning to learn.

Validity

Factor analytical studies on the WCST were conducted with schizophrenia and alcoholism patients (Koren et al., 1998; Sullivan et al., 1993), with a sample from rehabilitation centers and neuropsychology clinics (Greve et al., 1998), and with traumatic brain injury (TBI) patients (Greve et al., 2002). In these studies, three-factor solution is observed consistently. The first factor is called concept formation / perseveration (Greve et al., 1998; Koren et al., 1998; Sullivan et al., 1993) or cognitive flexibility (Greve et al., 2002), and it has loadings from total corrects, total errors, perseverative responses, perseverative errors, conceptual level responses, trials to make first category, and categories completed. The second factor has loading from either failure to maintain set (Koren et al., 1998; Sullivan et al., 1993) or nonperseverative errors (Greve et al., 1998; Greve et al., 2002). In this regard, FMS loads to the third factor when NPE is the second factor, and vice versa. Likewise, children's WCST performances revealed a three-factor solution (Yeniçeri & Altan-Atalay, 2008): (1) the conceptual thinking (including scores of total correct, nonperseverative errors, conceptual level response, and the percent conceptual level response), (2) perseveration (including perseverative responses, perseverative errors, and percent perseverative errors), and (3) set maintenance (including only failure to maintain set score).

Junior Brixton Spatial Rule Attainment Test (JBSRAT)

The JBSRAT is a neuropsychological instrument for the EF assessment of 7- to 12-year-old children (Shallice et al., 2002). It is adapted from the adult-version Brixton Spatial Rule Attainment Test. For the present study, the permission to use the JBSRAT in this study was obtained from Prof. Dr. Tim Shallice through personal contact with him (personal communication, May 30, 2008). With his referral, the test was obtained from his collaborator, Dr. Gian Marco Marzocchi (personal communication, June 2, 2008).

The JBSRAT consists of 45 A4 pages. Each page has a 2x5 array of turtles (i.e., 1 green, and 9 gray turtles). Pages differ from each other with respect to the position of the green turtle, and the participant's object is to guess the position of it in the consecutive card. The spatial position of the green turtle changes with respect to a certain rule. There are five blocks of trials in line with five different rules: (1) the position of green turtle increases by one (Rule +1), (2) decreases by one (Rule -1), (3) switches between 5 and 10 (Rule up down), (4) stays on 9 (Rule stay on the same place), and (5) switches between 4 and 10 (Rule alternate between 4-10). The movement rule changes after each nine trials, and the participant is not informed about rules or the time of rule change.

The Junior Brixton Test provides five scores: (1) total number of correct responses, (2) total number of errors, (3) perseveration errors, (4) plausible errors, and (5) guessing errors. The perseveration error ("Type I Error") refers to three types of behaviors: (a) perseveration of previous rule (the incorrect use of the previous rule), (b) perseveration of same response (repeatedly and incorrectly producing the same response), and (c) perseveration of same stimulus (pointing to the presented stimulus when it is not correct). Plausible errors (Type II Errors) are coded for the nonperseverative errors, which are spatially close to the stimulus turtle (i.e., top, down, left, right, or on a diagonal of the green turtle on the presented card). On the other hand, guessing errors ("Type III Errors") refer to the nonperseverative errors that are not spatially related to the stimulus turtle.

Reliability

The reliability of the JBSRAT is not indicated in the study of Shallice and colleagues (2002). Wood and Liossi (2007) found that the split-half reliability of the adult-version Brixton Test is 0.62, and the test-retest reliability is 0.71.

Validity

In the study of Shallice and colleagues (2002) children with ADHD displayed significantly poorer performance on this task than children in the control group, such that children with ADHD made excessive perseveration and guessing errors, which correspond to basic behavior of prefrontal patients. Therefore, the JBSRAT sensitively discriminates children with ADHD and typically developing children with respect to perseveration and guessing errors.

Backward Digit Span (BDS)

Digit Span subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R) is a verbal memory test, used for children aged 6 to 15 years old (Wechsler, 1974, as cited in Savaşır & Şahin, 1995). Savaşır and Şahin completed the Turkish standardization of the test in 1979 and provided the Turkish norms for the WISC-R (as cited in Savaşır & Şahin, 1995). In the Digit Span subtest, the child is read a digit-string, which is three-digit long in the first item and increases by one digit until the seventh item. The examiner reads each digit in one second. Then, the child is asked to recall the digit-string in the same order (Forward Digit Span) or in the opposite order (Backward Digit Span). In the present study only the Backward Digit Span (BDS) is used as a measure of WM capacity.

The BDS has seven trials, each of which has two attempts. If the child is successful in the two attempts of the same trial, his/her performance is scored two points. If s/he is successful only one of them, then his/her score is one point. Finally, if the child fails in both attempts of the same trial, the score is zero. The test is ended in the trial that child gets zero points.

Reliability

The reliability value for the Backward Digit Span is not available. Hence, the following reliability values are for the total Digit Span performances. The test-retest reliability of Digit Span is .73, and the split-half reliability is .85 (as cited in Kaufman, 1994). The correlation of Digit Span subtest with Verbal IQ and Performance IQ scores of the WISC-R is .42 for each, and with Full Scale IQ score is .46 (Savaşır & Şahin, 1995).

Validity

In the study of Brocki and Bohlin (2004), in which participants were 6- to 13-year-old children, the Backward Digit Span loaded on the WM factor together with Forward Digit Span, verbal fluency test, and the Stroop-like test. Therefore, the BDS is considered as a valid measure of WM capacity in children.

The Nonverbal Battery of Cognitive Abilities Test (CogAT®), Form 5

The Cognitive Abilities Test (CogAT®) Form 5 is developed in order to obtain information about the developmental level of cognitive skills for students from kindergarten to grade 12 (Thorndike & Hagen, 1994). The test basically measures the general overall reasoning ability (*g*) in learning and problem solving. In this regard, *g* is defined as abstract reasoning ability, specifically considering inductive reasoning—a crucial ability in acquiring new information, and in organization and storage of that information in memory (Thorndike & Hagen, 1994). The Cognitive Abilities Test is composed of three batteries, namely verbal, quantitative, and nonverbal, and a practice test including sample questions. The practice test is applied 2-7 days before the actual test application.

The Verbal Battery basically measures the verbal reasoning ability with respect to the primary mode of thinking in Western cultures. The Quantitative Battery—measuring quantitative reasoning—is crucial in understanding the participant's general problem solving ability and critical thinking. Finally, the Nonverbal Battery measures the general abstract reasoning abilities, which are minimally affected by cultural factors or previously learned information in school.

Different from Verbal and Quantitative tests, Nonverbal Battery presents novel tasks in order to measure the participant's ability to use his/her cognitive resources in new situations (Thorndike & Hagen, 1994). Hence, it is considered as measure of general reasoning ability in novel situations, especially abilities of abstract thinking and classification (Thorndike & Hagen, 1994).

CogAT® consists of different types of tests, which are developed for different grades: (1) Primary battery (Level 1 and 2) for participants from kindergarten to grade 3, and (2) Multilevel Battery (Levels A to H) for participants from grade 4 to 12. Each battery consists of the Verbal, Quantitative, and Nonverbal categories. In the present study, the Level 1 booklet of the Primary Battery of the Nonverbal CogAT® is used. The nonverbal CogAT® has two subtests: (1) Figure Classification—requiring the participant to find the similarities among three figures, generate the principle of the relationship among these figures, and choose the most appropriate response that goes with the presented figures with respect to the acquired principle, and (2) Matrices—which is an analogical reasoning test that requires the participant to detect the relationship between three figures in a matrix and to decide on the forth figure with respect to that relationship (Thorndike & Hagen, 1994). The CogAT® score refers to the total number of correct responses obtained in each subtest.

Reliability

Thorndike and Hagen (1994) administered CogAT® to children from kindergarten, grade 1, and grade 2 in two semesters. In fall, the Kuder Richardson 20 (KR20) values of the Nonverbal Primary Battery are 0.825 for kindergarten, 0.924 for grade

1, and 0.935 for grade 2. In spring, the reliability values are 0.889, 0.914, and 0.917 for kindergarten, grade 1, and grade 2, respectively. In addition, Alp and Diri (2003) examined the internal consistency of the test for Turkish students from kindergarten and grade 1, and they found that KR20 value for the entire test is 0.97.

Validity

Thorndike and Hagen (1994) indicate that scores on nonverbal battery positively correlate with children's academic performances (i.e., school grades) in reading, language, and mathematics in grades 1 and 2. Additionally, the nonverbal battery displays a low correlation with Verbal and Quantitative Batteries, which are indicators of crystallized intelligence. Since the nonverbal battery is a measure of fluid intelligence, the low correlation of the nonverbal battery with other two batteries is meaningful. Additionally, Alp and Diri (2003) found that CogAT® is a strong and reliable predictor of school achievement in Turkish students from kindergarten and grade 1. In this regard, the concurrent and predictive validity of CogAT® is supported since CogAT® predicts significantly not only the current school education but also the prospective one (Alp & Diri, 2003).

Procedure

The official permission from the Ministry of the National Education of Turkey was obtained in order to conduct this research in the randomly selected elementary schools in Istanbul. Afterwards, the examiner contacted with the principals of elementary schools. Finally, the present study was conducted in 4 elementary schools, of which 3 are public schools, and 1 is private. All of the administrations were held on school grounds during children's class time.

A consent form, explaining the aim and the procedure of the study, and the DIF were sent to the parents at least one week before administrations. The ones who agreed their child to participate in the study filled out both the consent form and the DIF. Copies of the concept form and the DIF were presented in Appendix A and Appendix B, respectively.

Administrations were held in two phases: (1) individual administrations, and (2) group administrations. Individual administrations included the Junior Brixton Spatial Rule Attainment Test (JBSRAT), the Wisconsin Card Sorting Test (WCST), and the Backward Digit Span (DBS), which were applied one by one to each child separately. The order of EF measures is counterbalanced, so that the administration orders are: (1) the JBSRAT, BDS, and the WCST, and (2) the WCST, BDS, and the JBSRAT. Participants were informed that none of these tests had time limits. Plus, the necessary instructions were provided in the beginning of each test, and no further information or guidance was given. Individual administrations lasted at most 40 minutes with each child.

Group administrations included administrations of the practice test and the Nonverbal Battery of CogAT®. The practice test was applied at least two days before the actual test administration. In a group session, 6 to 15 children were involved. The application of the practice test lasted at most 15 minutes, and the Nonverbal CogAT® was administered within a 30-minute time period. The necessary instructions were given at the beginning of each subtest. Participants were not given any additional information or guidance after the initial sample items. At the end, they received a pencil as a small gift for their participation in the study.

Method of Analysis

Two exploratory factor analyses (EFAs) were conducted for JBSRAT and WCST scores separately in order to investigate the internal structures of two EF tests. In this regard, principal components analysis (PCA) command of SPSS 16.0 was used. In each EFA, orthogonal rotation (varimax) with a criterion of eigenvalues greater than 1.0 was used. Rotated factor solution and the total variance explained with the observed factors were indicated in results. Plus, variance proportions and eigenvalues for each factor were illustrated. Relationships among corresponding factors of JBSRAT and WCST were explored via Pearson product- moment correlations among scores of two EF tests.

Relationships among EF, WM, and *gf* were explored through Pearson product-moment correlations among scores of WCST, JBSRAT, BDS, and nonverbal CogAT®. Then, effects of demographic variables on children's EF performances were explored via multivariate analysis of variance (MANOVA). Two MANOVAs were performed for the JBSRAT and the WCST separately. In each MANOVA, independent variables were age (6- and 7-year-olds), gender (males and females), grade (first and second grade), and type of school (public and private), and mothers' year spent in education was the covariate variable. The age comparisons were held for 6- and 7-year-olds due to small sample size for the 8-year-olds group. Nevertheless, the data of 8-year-olds were not included in the overall MANOVA automatically since MANOVA is conducted with the amount of data available for all of the variables. The overall MANOVA (Wilks' lambda) was calculated and univariate ANOVAs were obtained for each dependent variable. Multivariate and univariate F values were indicated in the results, and partial eta squares (η^2) used as an indication of effect size. Finally, effects of demographic variables on WM capacity and fluid intelligence were explored with 2 analysis of covariance (ANCOVA) tests conducted for the BDS and nonverbal CogAT® scores separately with same independent and covariate variables. The main effects and interactions were revealed from the ANCOVAs. The univariate F values and partial eta squares (η^2) were illustrated in the results.

CHAPTER 3

RESULTS

Descriptive Statistics

The participants' ages ranged from 6.0 to 8.11 years. Participants were categorized into 3 age groups. The first group includes participants whose ages ranged from 6.0 to 6.11 years with a mean of 6.6. In the second group, ages ranged from 7.0 to 7.11 years (*M* = 7.2). In the third age group, participants' ages ranged from 8.0 to 8.11 with a mean age of 8.2 years. The frequency distribution of participants with respect to age and gender is indicated in Table 1.

Table 1: The Frequency Distribution According to Age and Gender

		Gender		
		Female	Male	Total
Age	6-year-olds	24	21	45
	7-year-olds	32	27	59
	8-year-olds	8	8	16
	Total	64	56	120

Information about parental education was obtained through the Demographic Information Form (DIF). Maternal education ($M = 10.60$, $SD = 4.35$) and father education ($M = 11.44$, $SD = 3.77$) are continuous variables indicating years spent in education for each parent. There is a significantly high correlation between maternal education and father education [$r = .83$, $p < .01$], and the mean difference between these variables is less than one year of education. Therefore, maternal education is used in the statistical analyses as a representative of parental education. In addition, information about years spent in preschool, number of siblings, and birth order are obtained through DIF. To begin with the years spent in preschool, sample of the present study includes 28 participants who did not have any preschool experience. Additionally, there are 37 children with one year of experience, 20 children with 2 years of experience, and 32 children with 3 or more years of experience. Moreover, the cross tabulation of number of siblings and the birth order is indicated in Table 2.

Table 2: Cross tabulation of Number of Siblings and the Birth Order

		Birth Order			
		1st	2nd	3rd or later	Total
Number of Siblings	0	31			31
	1	29	33		62
	2 or more	3	6	16	25
	Total	63	39	16	118

Participants' performances on the Wisconsin Card Sorting Test (WCST), the Junior Brixton Spatial Rule Attainment Test (JBSRAT), the Nonverbal Cognitive Abilities Test (CogAT®), and the Backward Digit Span (BDS) are observed with respect to the specific scores of the test variables. The raw scores were used in the statistical analyses. The mean scores, standard deviations, and minimum and maximum values for the test variables are presented in Table 3.

Table 3: Means, Standard Deviations, Minimum and Maximum Values

Test Variables	M	SD	Min	Max	N
WCST-TA	126.53	5.93	89	128	121
WCST-TC	57.86	20	19	99	121
WCST-TE	68.66	22.09	18	109	121
WCST-PR	35.58	20.51	6	121	121
WCST-PE	30.73	15.33	6	91	121
WCST-NPE	37.91	20.99	3	91	121
WCST-CLR	39.28	24.63	0	89	121
WCST-CC	2.23	1.94	0	6	121
WCST-TC1st	58.61	46.84	10	129	121
WCST-FMS	1.04	1.25	0	7	121
WCST-LL	-5.82	10.31	-37.50	28.79	63
JBSRAT-TC	24.86	7.58	2	35	121
JBSRAT-TE	19.13	7.58	9	42	121
JBSRAT-PER	9.52	3.48	2	24	121
JBSRAT-PLA	5.00	3.34	0	18	121
JBSRAT-GUE	4.50	5.07	0	26	121
BDS	3.55	1.40	0	9	121
COGAT®-NB	26.12	7.87	11	39	119

Note. WCST: Wisconsin Card Sorting Test, TA: Trials administered, TC: Total correct responses, TE: Total errors, PR: Perseverative responses, PE: Perseverative errors, NPE: Nonperseverative errors, CLR: Conceptual level responses, CC: Categories completed, TC1st: Trials to complete the first category, FMS: Failure to maintain set, LL: Learning to learn, JBSRAT: Junior Brixton Spatial Rule Attainment Test, PER: perseveration errors, PLA: Plausible errors, GUE: Guessing errors, BDS: Backward Digit Span, CogAT®-NB: The nonverbal battery of the Cognitive Abilities Test.

Pearson Product-Moment Correlations

Pearson product-moment correlations were held in order to examine the relationship among scores of the WCST, the JBSRAT, the BDS, and the nonverbal CogAT®. The correlation coefficients are displayed in Table 4. Considering correlations among WCST and JBSRAT scores, the total correct score of the JBSRAT is significantly correlated with 8 scores of the WCST, that are total correct (WCST-TC) [$r = .29$, $p < .01$], total errors (WCST-TE) [$r = -.31$, $p < .01$], perseverative responses (WCST-PR) [$r = -.19$, $p < .05$], perseverative errors (WCST-PE) [$r = -.20$, $p < .05$], nonperseverative errors (WCST-NPE) [$r = .18$, $p < .05$], conceptual level response

(WCST-CLR) [$r = .31$, $p < .01$], categories completed (WCST-CC) [$r = .30$, $p < .01$], and trials to first category (WCST-TC1st) [$r = -.22$, $p < .05$]. Secondly, the plausible errors score of the JBSRAT is significantly correlated with 6 scores of the WCST, which are WCST-TC [$r = -.28$, $p < .01$], WCST-TE [$r = .30$, $p < .01$], WCST-NPE [$r = .20$, $p < .05$], WCST-CLR [$r = -.31$, $p < .01$], WCST-CC [$r = -.35$, $p < .01$], and WCST-TC1st [$r = .20$, $p < .01$]. Finally, the guessing error score of the JBSRAT is significantly correlated with 5 scores of the WCST, which are WCST-TC [$r = -.24$, $p < .01$], WCST-TE [$r = .24$, $p < .01$], WCST-CLR [$r = -.23$, $p < .01$], WCST-CC [$r = -.20$, $p < .05$], and WCST-TC1st [$r = .18$, $p < .05$]. On the other hand, perseveration score of the JBSRAT is not correlated with any of the WCST scores.

The BDS score is significantly correlated with 7 scores of the WCST: (1) WCST-TC [$r = .32$, $p < .01$]; (2) WCST-TE [$r = -.31$, $p < .01$]; (3) WCST-NPE [$r = -.20$, $p < .05$]; (4) WCST-CLR [$r = .31$, $p < .01$]; (5) WCST-CC [$r = .26$, $p < .01$]; (6) WCST-TC1st [$r = -.19$, $p < .05$]; and (7) failure to maintain set (WCST-FMS) [$r = .19$, $p < .05$]. Additionally, the BDS score is significantly correlated with 4 scores of the JBSRAT, which are total correct (JBSRAT-TC) [$r = .32$, $p < .01$], total errors (JBSRAT-TE) [$r = -.32$, $p < .01$], plausible errors (JBSRAT-PLA) [$r = -.21$, $p < .05$], and guessing errors (JBSRAT-GUE) [$r = -.23$, $p < .01$]. Furthermore, the total score of the nonverbal CogAT® is significantly correlated with 6 scores of the WCST, that are WCST-TC [$r = .26$, $p < .01$], WCST-TE [$r = -.31$, $p < .01$], WCST-NPE [$r = -.26$, $p < .01$], WCST-CLR [$r = .28$, $p < .01$], WCST-CC [$r = .30$, $p < .01$], and WCST-TC1st [$r = -.19$, $p < .05$]. Plus, it is correlated with total correct [$r = .24$, $p < .05$] and total errors [$r = -.24$, $p < .05$] scores of the JBSRAT. Finally, the correlation between BDS and nonverbal CogAT® is statistically significant, $r = .42$, $p < .01$.

Table 4: Correlation Matrix for the Test Variables of the Study

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. WCST-TC	1															
2. WCST-TE	-.965**	1														
3. WCST-PR	-.356**	.379**	1													
4. WCST-PE	-.385**	.416**	.992**	1												
5. WCST-NPE	-.734**	.748**	-.325**	-.292**	1											
6. WCST-CLR	.971**	-.966**	-.412**	-.438**	-.696**	1										
7. WCST-CC	.808**	-.861**	-.359**	-.382**	-.626**	.867**	1									
8. WCST-TC1st	-.677**	.676**	.247**	.258**	.523**	-.695**	-.767**	1								
9. WCST-FMS	.581**	-.522**	-.327**	-.335**	-.304**	.576**	.211*	-.172	1							
10. JBSRAT-TC	.296**	-.312**	-.196*	-.203*	-.180*	.318**	.300**	-.222*	.132	1						
11. JBSRAT-TE	-.296**	.312**	.196*	.203*	.180*	-.318**	-.300**	.222*	-.132	-1**	1					
12. JBSRAT-PER	.053	.050	.106	.101	-.021	-.076	-.043	.069	-.077	-.263**	.263**	1				
13. JBSRAT-PLA	-.285**	.309**	.155	.165	.205*	-.310**	-.355**	.205*	-.024	-.735**	.735**	-.103	1			
14. JBSRAT-GUE	-.243**	.249**	.120	.130	.168	-.235**	-.208*	.189*	-.135	-.784**	.784**	-.208*	.522**	1		
15. BDS	.323**	-.313**	-.148	-.162	-.209*	.315**	.260**	-.194*	.192*	.329**	-.329**	-.154	-.217*	-.235**	1	
16. COGAT®-NB	.267**	-.313**	-.080	-.088	-.263**	.284**	.305**	-.196*	.152	.242*	-.242*	-.159	-.134	-.173	.429**	1

Note. * p< .05, ** p< .01 (two tailed). WCST: Wisconsin Card Sorting Test, TA: Trials administered, TC: Total correct responses, TE: Total errors, PR: Perseverative responses, PE: Perseverative errors, NPE: Nonperseverative errors, CLR: Conceptual level responses, CC: Categories completed, TC1st: Trials to complete the first category, FMS: Failure to maintain set, JBSRAT: Junior Brixton Spatial Rule Attainment Test, PER: perseveration errors, PLA: Plausible errors, GUE: Guessing errors, BDS: Backward Digit Span, CogAT®-NB: The nonverbal battery of the Cognitive Abilities Test.

Principal Components Analyses

Junior Brixton Spatial Rule Attainment Test (JBSRAT)

Four scores of the JBSRAT, which are total errors, perseveration errors, plausible errors, and guessing errors, from all 121 subjects were entered into a PCA with varimax rotation. Two factors, explaining 87.3% of the variance, emerged with eigenvalues greater than 1.0. The first factor accounted for 59.1% of the variance, and had loadings from total, plausible, and guessing errors. Higher scores on these variables (total, plausible, and guessing error) indicate inefficient rule-use, which is related to the poor concept formation. Therefore, this factor is called concept formation. The second factor explained 28.1% of the variance, and had loading from perseveration score, representing poor set shifting. Hence, the second factor is considered as the perseveration tendency. Factor loadings are displayed in Table 5.

Table 5: Principal Components Analysis of the JBSRAT

	Factor	
	1	2
Variance Proportion	59.1	28.1
Eigenvalue	2.3	1.1
Total Errors	.946*	.292
Guessing Errors	.871*	-.207
Plausible Errors	.844*	-.067
Perseveration Errors	-.025	.997*

Note. Principal components analysis with orthogonal (varimax) rotation (N = 121). * score with high and relatively nonoverlapping loading on the factor.

Wisconsin Card Sorting Test (WCST)

WCST provides 15 scores, and some of them are redundant in the presence of others, such that total correct score is not necessary when total errors is included in the analyses or percentage scores do not need to be used in the presence of corresponding raw scores. Therefore, 7 scores of the WCST, which are total errors (TE), perseverative errors (PE), nonperseverative errors (NPE), conceptual level response (CLR), categories completed (CC), trials to complete first category (TC1st), and failure to maintain set (FMS), were chosen and subjected to a principal components analysis (PCA) with an orthogonal (varimax) rotation. However, the observed extraction value for FMS score was small (.400), indicating a poor fit to the factor solution and should be excluded from the analysis. Hence, another PCA with varimax rotation is conducted with 6 scores of the WCST for a sample of 121 participants. With a criterion of eigenvalues greater than 1.0, there found a two-factor solution explaining 89.5% of the variance. The first factor, accounting for 68.3% of the variance, had loadings from TE, NPE, CLR, CC and TC1st scores. This factor refers to the concept formation. The second factor, explaining 21.1% of the variance, consisted only of PE score, representing the perseveration tendency. Factor loadings are displayed in Table 6.

Table 6: Principal Components Analysis of the WCST

	Factor	
	1	2
Variance Proportion	68.3	21.1
Eigenvalue	4.1	1.2
Total Errors	.954*	.162
Conceptual Level Response	-.946*	-.206
Categories Completed	-.918*	-.194
Nonperseverative Errors	.828*	-.532
Trials to Complete 1st Category	.807*	.117
Perseverative Errors	.240	.963*

Note. Principal components analysis with orthogonal (varimax) rotation (*N* = 121). * score with high and relatively nonoverlapping loading on the factor.

Effects of Demographic Variables

A MANOVA was conducted using age (6- and 7-year-olds), gender (males and females), grade (1 and 2), and type of school (public and private) as independent variables, and 6 scores of the WCST (TE, PE, NPR, CLR, CC, and TC1st) as dependent variables. The year of maternal education was entered into the analysis as a covariate. Results revealed that maternal education was found as a significant covariate, $F(5, 85) = 2.461$, $p < .05$, $\eta^2 = .126$. On the other hand, neither the main effects nor the interactions among independent variables were statistically significant. F values and partial eta squares (η^2) for the multivariate tests are illustrated in Table 7.

Table 7: Multivariate Tests Results of MANOVA for the WCST

Variables	F	η^2
Maternal Education	2.461*	.126
Age	.557	.032
Gender	.934	.052
Grade	.116	.007
Type of School	1.832	.097
Age*Gender	.149	.009
Gender*Grade	.419	.024
Gender*Type of School	.277	.016

Note. $*p < .05$.

Tests of between subjects effects, which are univariate ANOVAs, revealed that maternal education is a significant covariate for TE, NPE, CLR, and CC scores of the WCST, $F(1, 85) = 8.199, p < .01, \eta^2 = .084$; $F(1, 85) = 6.812, p < .05, \eta^2 = .071$; $F(1, 85) = 4.828, p < .05, \eta^2 = .051$; and $F(1, 85) = 4.217, p < .05, \eta^2 = .045$, respectively.

Another MANOVA, using age, gender, grade, and type of school as independent variables and maternal education as covariate, was performed for total errors, plausible and guessing errors, and perseveration scores of the JBSRAT. Results indicated that maternal education was found as a significant covariate, $F(4, 86) = 3.254, p < .05, \eta^2 = .131$. In addition, the main effect of gender, $F(4, 86) = 3.919, p < .01, \eta^2 = .154$, and the interaction between age and gender, $F(4, 86) = 3.601, p < .01, \eta^2 = .143$, are statistically significant. Plus, the interaction between gender and grade approaches significance, $F(4, 86) = 2.483, p = .05, \eta^2 = .104$. On the other hand, other main effects and interactions were not significant. F values and partial eta squares (η^2) for the multivariate tests are illustrated in Table 8.

Table 8: Multivariate Tests Results of MANOVA for the JBSRAT

Variables	*F*	η^2
Maternal Education	3.254*	.131
Age	1.685	.073
Gender	3.919**	.154
Grade	1.215	.053
Type of School	.671	.030
Age*Gender	3.601**	.143
Gender*Grade	2.483	.104
Gender*Type of School	2.052	.094

Note. *$p < .05$, **$p < .01$.

In addition, univariate ANOVAs were used to interpret the significant main effects and interactions for each dependent variable. First of all, maternal education is found as a significant covariate for total errors, $F(1, 86) = 10.275, p < .01, \eta^2 = .103$; perseveration errors, $F(1, 86) = 5.419, p < .05, \eta^2 = .057$; and plausible errors, $F(1, 86) = 5.977, p < .05, \eta^2 = .063$. Secondly, the main effect of gender is statistically significant for total errors, $F(1, 86) = 6.422, p < .05, \eta^2 = .067$; and perseveration, $F(1, 86) = 12.165, p < .01, \eta^2 = .120$, indicating that females make more total error or perseveration than males on the JBSRAT. Moreover, there is a significant interaction of age and gender on perseveration errors, $F(1, 86) = 14.227, p < .001, \eta^2 = .138$, suggesting that the main effect of gender on perseveration disappears in 7-year-olds group. Independent samples t-tests revealed that 6-year-old females ($M = 11.29$, $SD = 4.12$) make more perseveration errors than 6-year-old males ($M = 8.90$, $SD = 2.25$), $t\ (43) = 2.448$, p < .05, whereas the gender difference is not statistically significant for 7-year-olds [$t\ (57) = .604$, p > .05]. Finally, since the interaction of gender and grade approaches significance in the multivariate test results ($p = .05$), univariate test results for this interaction are considered and it is found that there is a significant interaction of gender and grade on perseveration scores, $F(1, 89) = 9.523$, $p < .05$, $\eta^2 = .097$. In order to evaluate the meaning of this interaction, independent sample t-tests comparing different gender and grade groups were held. Nevertheless, this interaction does not seem statistically meaningful since independent sample t-tests do not reveal any significant difference between (i) first grader females (*M* = 10.09; *SD* = 3.60) and second grader females (*M* = 10.21; *SD* = 4.04) [t (54) = -.123, p > .05]; (ii) first grader males (*M* = 9.20; *SD* = 2.21) and second grader males (*M* = 8.52; *SD* = 2.12) [t (46) = 1.079, p > .05]; (iii) first grader females (*M* = 10.09; *SD* = 3.60) and first grader males (*M* = 9.20; *SD* = 2.21) [t (56) = 1.087, p > .05]; and (iv) second grader females (*M* = 10.21; *SD* = 4.04) and second grader males (*M* = 8.52; *SD* = 2.12) [t (44) = 1.779, p > .05].

Two univariate analysis of covariance (ANCOVA) tests were held for BDS and CogAT® scores separately. Age, gender, grade, and type of school were independent variables, and maternal education was the covariate. To begin with the BDS score, maternal education was found as a significant covariate, $F(1, 89) = 4.133$, $p < .05$, $\eta^2 = .044$, whereas other main effects and interactions were not statistically significant. Secondly, ANCOVA for the total score of the nonverbal CogAT® revealed that neither the main effects and covariates, nor the interactions were statistically significant.

CHAPTER 4

DISCUSSION

Assessment of Executive Functions: Internal Structures of Measures

The present study revealed that both of the executive function (EF) measures, the Wisconsin Card Sorting Test (WCST) and the Junior Brixton Spatial Rule Attainment Test (JBSRAT), are composed of two factors, namely concept formation and perseveration (or cognitive inflexibility) in a sample of 6- to 8-year-old children. Hence, results are in line with the argument that some of the EF measures, such as the WCST and the JBSRAT, embrace more than one cognitive capacity (Baron, 2004). To be more specific, the present study supports previous findings that indicated specific WCST scores load on different factors rather than being categorized under one factor (Greve et al., 1998; Greve et al., 2002; Greve et al., 2005; Koren et al., 1998; Lee et al., 2004; Sullivan et al., 1993; Yeniçeri & Altan-Atalay, 2008). Additionally, the internal structure of the JBSRAT is a supporting evidence for the argument that the Brixton Test is mainly composed of concept formation and shifting abilities (Burgess & Shallice, 1996; Drake & Lewis 2003; Wood & Liossi, 2007). The internal structures of these tests are considered here separately with respect to consistencies and inconsistencies with the previous research.

Wisconsin Card Sorting Test

Regarding the internal structure of the WCST, a sample of 6- to 8-year-old children's WCST performances revealed a two-factor solution. The first factor, named concept formation, was composed of total errors (TE), conceptual level response (CLR), categories completed (CC), nonperseverative errors (NPE), and trials to complete first category (TC1st) scores of the WCST. The second factor, perseveration (or cognitive inflexibility), included only perseverative errors (PE) score.

There are several studies investigating the factorial structure of the WCST in different adult patient groups, such as patients with schizophrenia (Koren et al., 1998; Sullivan et al., 1993), patients with traumatic brain injury (TBI) (Greve et al., 2002), and other neuropsychiatric patients (Greve et al., 1998; Greve et al., 2005). However, studies investigating the factorial structure of the WCST in children are rather limited (i.e., Lee et al., 2004; Yeniçeri & Altan-Atalay, 2008). Studies with adult patient groups consistently indicate a three-factor solution, and the first factor includes both the concept formation and perseveration scores (Koren et al., 1998; Greve et al., 1998; Greve et al., 2002; Greve et al., 2005; Sullivan et al., 1993). On the other hand, concept formation and cognitive inflexibility domains emerged as two different factors in studies with children (i.e., Lee et al., 2004; Yeniçeri & Altan-Atalay, 2008). A two-factor solution for the WCST is observed in this study, which provides a further contribution to these findings suggesting that differentiation of concept formation and perseveration is also the case for 6- to 8-year-olds' WCST performances.

There is an argument that perseveration errors do not have to be associated with the inhibition problems in every case, but can also be related with non-inhibitory processes (as cited in Cinan, 2006). Therefore, Cinan (2006) differentiates two kinds of cognitive inflexibility: (1) “representational inflexibility”, and (2) “switching inflexibility” (p. 378). Representational inflexibility refers to the perseveration of an inadequate response when the correct rules or concepts are not formed, whereas in switching inflexibility, participant forms the correct representation of rules or concepts, but cannot apply them in a flexible manner due to the failure of inhibiting the prepotent response. With respect to this categorization, Cinan (2006) claimed that higher scores on the number of categories completed are associated with the abilities of switching and concept formation at the same time, whereas lower scores do not indicate a problem of switching inflexibility, but certainly refers to problems in concept formation. In the study of Cinan (2006), younger children (*M* = 78 months) achieved fewer categories successfully and used more trials to achieve the second and third categories than middle (*M* = 102 months) and older (*M* = 139 months) age groups. In this regard, younger children were found to have problems of concept formation, and their perseverative behaviors were due to representational inflexibility (Cinan, 2006). These findings suggest that the inflexibility type may change with respect to the age of the child.

Considering the concept formation, it is claimed that that there are different developmental patterns for different components of concept formation (i.e., concept recognition, articulation, and sorting), so that participants’ problem areas in these cognitive domains may change with respect to their age and developmental level (Greve, Love, Dickens, & Williams, 2000). What’s more, Greve and colleagues (2000) argued that these components have not completely developed yet in young school-age children. Hence, children's concept formation capacity also changes with respect to age and their developmental level. In addition to these findings, present study suggests that the concept formation and cognitive flexibility capacities are diverse from each other at 6 to 8 years of age.

Several researchers stressed that WCST performance requires problem solving, working memory, shifting and inhibition (Kane & Engle, 2002; Miyake et al., 2002; Shallice, 1982; Shallice et al., 2002; Somsen, 2007; Somsen et al., 2000), and different developmental processes may be involved in these cognitive components (Miyake et al., 2002; Pennington et al., 1996). For instance, Miyake et al. (2002) indicated that shifting, updating, and inhibition are distinct abilities that share an underlying commonality. Likewise, Pennington and colleagues (1996) argued that processes of working memory and inhibition are independent from each other although inhibition is an essential component in working memory capacity. With respect to these, distinction of concept formation and perseveration may be related to different developmental capacities and processes involved for each. In this regard, the present study revealed that the working memory measure, the Backward Digit Span (BDS), is significantly correlated with all of the WCST scores in the concept formation factor, whereas it is not significantly related with perseveration. This result is consistent with the study of Yeniad (2009), which also found that BDS score was significantly correlated with TE, CLR, CC, and trials to complete the first category scores, but not with perseveration scores of the WCST in a sample of 6- to 7-year-old children. Therefore, the observed factors may be associated with the differential role of working memory on concept formation, whereas perseveration stands as a distinct domain that is not related to the working memory capacity at this age period. The effect of inhibition is not explored in the present study due to the absence of a separate inhibition measure.

Junior Brixton Spatial Rule Attainment Test

The present study is the first study investigating the factorial structure of the JBSRAT. Four scores of the JBSRAT were categorized into two factors, which are called concept formation and perseveration. The concept formation factor includes total errors, plausible errors, and guessing errors scores of the JBSRAT, whereas the perseveration factor includes perseveration errors score. Adult-version Brixton Test is considered as a rule attainment test, which includes the concept formation and set shifting abilities (Burgess & Shallice, 1996; Drake & Lewis 2003; Wood & Liossi, 2007). In this regard, the findings of present study support this conceptualization for the child-version of the Brixton Test.

The JBSRAT scores in the first factor mainly indicate one's difficulty in concept formation or rule-induction. For instance, total errors score is associated with a general difficulty in abstraction of rules, and rule-application throughout the test. Likewise, plausible and guessing errors indicate that participant cannot derive the correct rule from the test and tries to figure it out through these error trials in a nonperseverative manner (Shallice et al., 2002). The only difference between plausible errors and guessing errors is that the former bases on a spatially figured-out rule, whereas the latter one refers to made-up responses that do not have any spatial base. On the other hand, the perseveration errors in the JBSRAT indicate a difficulty in mental set shifting even though the concept formation capacity is intact. Therefore, similar to the WCST, the JBSRAT performances of children with 6 to 8 years of age are characterized by two different cognitive components, which are concept formation and cognitive inflexibility (or perseveration), and this solution supports previous arguments claiming that cognitive flexibility and concept formation are distinctly developed capacities (Cinan, 2006; Greve et al., 2000).

Additionally, the role of working memory in this factorial structure is explored for the JBSRAT. Similar to the WCST, it is found that BDS is significantly correlated with the concept formation scores of the JBSRAT, but not with the perseveration score. Therefore, it is suggested that different developmental patterns are possible for the concept formation and mental set shifting abilities in relation with distinct processes of working memory and inhibition. However, the effect of inhibition should also be examined in further studies in order to obtain a comprehensive explanation.

The Validity of the JBSRAT

In the present study, similar factorial components were observed for two EF tests, the WCST and the JBSRAT, in a sample of 6- to 8-year-old children. By comparing the internal structure of the JBSRAT vis-à-vis the internal structure of the WSCT, the present study indicates that the JBSRAT is valid instrument in the assessment of EF of 6- to 8-year-old Turkish students.

In order to evaluate the similarities and differences between the WCST and the JBSRAT, statistical correlations among scores in the corresponding factors are examined. To begin with the concept formation factor, it is observed that each of the concept formation scores of the JBSRAT (i.e., total, plausible, and guessing errors) is significantly correlated with the concept formation scores of the WCST (i.e., TE, CLR, CC, TC1st, and NPE) separately, except the correlation between guessing errors and NPE. In this regard, present study claims that the concept formation factors of both tests are related to each other, but it cannot be suggested that these factors are almost identical since correlations among those scores are at the moderate level.

Regarding the concept formation factors of both tests, present findings provide evidence for the arguments of Burgess and Shallice (1996) and Shallice et al. (2002) that there are differences between the WCST and the adult and child versions of the Brixton Test. For instance, it is claimed that both versions of the Brixton Test have more abstract rules than the WCST because of the fact that rules of the Brixton Test rely on relationship between consecutive cards, whereas rules of the WCST depend on a perceptually salient stimulus (i.e., color, form, and number), which provides easier access to relevant schemas and other representations (Burgess & Shallice, 1996; Shallice et al., 2002). Additionally, Shallice et al. (2002) argued that rules of the JBSRAT are less likely to be overlearned than the WCST because of the fact that rules of the JBSRAT do not change with respect to a set of consecutive correct responses, but change after every 9 trials. Moreover, the first 3 rules of the WCST (sorting with respect to color, form, and number) were duplicated after the completion of third category, whereas in the JBSRAT, participant has to infer a different rule after each 9 trials. Considering these, moderate correlations among concept formation scores of two tests may be associated with these differences between the JBSRAT and the WCST.

Besides, correlations among perseveration scores of the tests revealed that perseveration factors of the JBSRAT and the WCST are not statistically related to each other although these tests have a perseveration component. Hence, the

JBSRAT and the WCST differ with respect to the perseveration types they measure, and the most prominent reason for this would be the difference in their perseveration definitions. For instance, although perseveration generally refers to the application of the previous rule incorrectly, the JBSRAT includes two additional perseverative response patterns that are irrelevant for the WCST: perseveration of same response (PSR), and perseveration of same stimulus (PSS). The PSR indicates perseveration of pointing to the same turtle (i.e., third turtle), and this type of perseveration cannot be coded in the WCST since consistently pointing to the same card (i.e., choosing the second stimulus card) would mean a different type of response in each trial with respect to the features of the matched cards. Additionally, in the case of PSS, it is assumed that the participant is perceptually dominated by the external stimulus (i.e., the green turtle in the JBSRAT), and cannot inhibit the tendency to choose the green turtle in the presented card (Shallice et al., 2002). Nevertheless, this type of perseveration is also irrelevant for the WCST since the participant cannot choose the presented card, but should match it with one of the stimulus cards. Considering these, the insignificant correlation between perseveration scores of both tests may result from the fact that the perseveration score of the JBSRAT embraces more extensive behavioral patterns of cognitive inflexibility in comparison to the WCST. This conclusion is in line with the argument of Shallice and colleagues (2002) that the perseveration score of the JBSRAT is more sensitive in differentiating children with and without ADHD in comparison to the perseverative errors score of the WCST. For instance, Shallice et al. (2002) indicated that children with ADHD made more perseverative errors on the JBSRAT than typically developing children did. In contrast, some studies revealed that the ADHD and non-ADHD groups do not differ on the perseverative errors score of the WCST (i.e., Pennington et al., 1993).

Nevertheless, further investigation is necessary for a comprehensive understanding of similarities and differences of perseverative behaviors measured by these tests since the JBSRAT is a newly adapted EF measure for children.

Use of the JBSRAT and the WCST as an Alternative to the Other

A crucial question regarding these EF tests would be whether or not these tests can be used as an alternative to the other. Regarding this question, the present study investigated the internal structure of both tests and the statistical correlations among their scores in a sample of 6- to 8-year-old Turkish students. Results suggest that although the JBSRAT and the WCST provide assessment of similar components (i.e., concept formation and cognitive inflexibility), these capacities do not refer to identical constructs. More specifically, the concept formation scores of the JBSRAT and the WCST are moderately related, whereas the perseveration factors are not related to each other. In this regard, present study cannot claim that the JBSRAT and the WCST can be used as an alternative to each other, but both tests have some advantages and disadvantages in comparison to the other.

EF deficit is crucial in several neuropsychological disorders, i.e., ADHD, autism spectrum disorder, schizophrenia, alcoholism, Tourette syndrome, learning disability, traumatic brain injury, and frontal lesions (Barkley, 1997; Greve et al., 1998; Greve et al., 2002; Greve et al., 2005; Griffith et al., 1999; Koren et al., 1998; Noel et al., 2001; Sullivan et al., 1993; Zelazo et al., 1997). In each of these disorders, different EF components are impaired rather than having a universal EF deficit (Gioia et al., 2001). Hence, the JBSRAT and the WCST are important screening instruments detecting specific impairments in concept formation and cognitive flexibility.

In the clinical literature, it is generally suggested that the most prominent frontal behavior in the case of EF impairment is perseveration, which results from difficulty in inhibition and poor shifting capacity (Barkley, 1997; Burgess & Shallice, 1996; Drake & Lewis, 2003; Shallice et al., 2002; Sullivan et al., 1993). In this regard, both the WCST and the JBSRAT are considered as sensitive measures for the perseverative behavior (Burgess & Shallice, 1996; Heaton, 1981; Shallice et al., 2002; Sullivan et al., 1993). For instance, Sullivan et al. (1993) claimed that perseveration factor of the WCST was a delicate measure for the frontal dysfunction of patients with schizophrenia. Additionally, Shallice et al. (2002) found that perseveration errors in the JBSRAT clearly differentiate ADHD and non-ADHD groups, i.e., children with ADHD made more perseveration errors than controls. Nevertheless, present findings suggest that perseveration measures of two tests are not associated with each other, indicating that perseveration in the WCST is distinct from perseveration in the JBSRAT. This distinction may result from the fact that the JBSRAT embraces different types of perseverations that are not coded in the WCST, so that one of the strengths of the JBSRAT over the WCST would be that it provides a more sensitive measure of perseveration (i.e., perseverations of previous rule, same response, and same stimulus) in comparison to the WCST that only measures the perseveration of previous rule.

Besides, Burgess and Shallice (1996) stressed that frontal patients' behaviors do not only consist of perseverative responses, but also involve impulsive, risk-taking responses. In this regard, another strength of the JBSRAT in comparison to the WCST is that JBSRAT detects both impulsive responses and perseveration. For instance, guessing responses in the JBSRAT are made-up responses that do not rely on any spatially meaningful rule, so that those responses are considered as an indicator of impulsivity (Burgess & Shallice, 1996; Shallice et al., 2002). What is more, guessing responses can differentiate clinical and non-clinical groups. For instance, the study of Noel et al. (2001) revealed that alcoholics made more guessing errors than controls, whereas groups were almost even on their perseveration errors.

It should be noted that one of the strengths of the WCST as a screening instrument is its richness of concept formation scores, so that it provides more specific information about one's achievements and failures in concept formation in comparison to the JBSRAT. Although the JBSRAT presents different error scores capturing several types of frontal behaviors, it only has the total correct score as an indicator of one's strength in the test. However, in addition to total number of correct responses, the WCST provides information about one's capacity of initial conceptualization (i.e., trials to make the first category), strengths and weaknesses in rule or concept maintenance (i.e., CC and FMS), capacity of conceptual understanding (i.e., CLR), and learning efficiency (i.e., LL) (Heaton, 1981).

The final point regarding the comparisons of these two tests is drawn from the observations from data collection phase of the present study. It was noted that the administration of the JBSRAT is easier than the WCST since it takes approximately 15 minutes to administer, whereas the WCST takes at least 30 minutes with each child. In addition, when children were asked about their impressions about these tests after the administrations, they generally indicated that the WCST is a bit boring, but taking the JBSRAT is more fun.

Considering all, it is claimed that the JBSRAT and the WCST are not used interchangeably, but they are valid screening instruments for measuring executive functioning, and at least one of them should be included in the neuropsychological assessment batteries with respect to the aforementioned suggestions and the requirements of the assessment.

Executive Functions, Working Memory, and Fluid Intelligence

Another purpose of the present study was to investigate the relationships among EF, working memory (WM), and general fluid intelligence (*gf*) with respect to the correlations among the WCST, the JBSRAT, the BDS, and the nonverbal Cognitive Abilities Test (CogAT®). The BDS is a measure of WM capacity in children (Bull et al., 2008), and higher scores on the BDS indicate greater WM capacity. On the other hand, the nonverbal CogAT® is a measure of *gf* (Alp & Diri, 2003), and higher scores on the nonverbal CogAT® correspond to higher-level nonverbal reasoning ability. Results of the present study revealed significant correlations among EF, WM, and *gf* measures, and these correlations are evaluated with respect to three headings: (1) the relationship between EF and WM, (2) the relationship between WM and *gf*, and (3) the relationship between EF and *gf*.

The Relationship between Executive Functions and Working Memory

The present study suggested that the WM measure is significantly correlated with the concept formation scores of EF tests. More specifically, as the BDS score increases, (1) there is an increase in the TC, CLR, and CC scores of the WCST, and the TC score of the JBSRAT; and (2) there is a decrease in the WCST scores of TE, NPE, and trials to complete the first category, and in the JBSRAT scores of total, plausible and guessing errors. On the other hand, correlations between BDS and perseveration scores are not statistically significant. Therefore, the present study suggests that EF and WM are associated through the relationship of WM with concept formation ability in a sample of 6- to 8-year-old children. This finding is in line with the study of Yeniad (2009), which also indicated a significant relationship between similar scores of the WCST and the BDS in a sample of 6- to 7-year-old children.

WM refers to the capacity of active maintenance and manipulation of temporarily available environmental stimuli for the cognitive task performance (Daneman & Carpenter, 1980). Several theoretical models of EF stress the importance of WM in executive functioning since WM provides appropriate storage and manipulation of the task-relevant information (Anderson, 2002; Barkley, 1997; Lezak, 1982; Roberts & Pennington, 1996; Shallice, 1982; Zelazo et al., 1997). What is more, it is claimed that WM and EF involve inter-related processes, such that WM is considered as one of the EFs (Barkley, 1997; Roberts & Pennington, 1996; Miyake et al., 2002), and EF is considered as one of the components of WM (Oberauer et al., 2003). For instance, Miyake et al. (2002) indicated that updating ability relies more on the WM capacity in comparison to inhibition and shifting. In addition, Oberauer et al. (2003) indicated that WM consists of three factors (i.e., storage and processing, supervision, and relational coordination) and the supervision factor involves executive processes, such as shifting. The findings of the present study provide a supporting evidence for these conceptualizations, suggesting that the WM capacity is involved in participants’ performances in EF tasks, especially in the concept formation component.

It is known that WM is responsible for the storage of information and processing via controlled attention, and this capacity is crucial in performing the WCST and the JBSRAT. These EF tasks require capacity to hold information in mind (i.e., remembering the initial sorting rule and the feedback to that response in the WCST, or remembering the position of the green turtle between consecutive cards in the JBSRAT), and manipulation of information when necessary (i.e., changing "the sorting rule" or "the spatial rule" with respect to the feedback). In this regard, Nyhus and Barcelo (2009) underlined that positive or negative feedback in the WCST is associated with the mid dorsolateral prefrontal cortex (dPFC), which is associated with the processing component of the WM. Additionally, Reverberi, Agostini, Skrap, and Shallice (2005) suggested that deficit in the rule abstraction in the Brixton Test would be associated with WM deficit. Therefore, the significant correlations between BDS and the concept formation scores of the EF tests in the present study are meaningful since both tests are assumed to require WM capacity.

Nevertheless, present study does not support the association of increased perseverative tendency with poor WM capacity, which was indicated in previous research (i.e., Cepeda & Munakata, 2007). For instance, Cepeda and Munakata (2007) explored the relationship between perseveration and WM capacity in a sample of children aged 5.7 to 6.9 years, and suggested that the main difference between switchers and perseverators is not about perseverators' poorer inhibitory mechanisms, but about switchers' greater WM capacity. However, present study suggests that participants' perseverative behavior is not related to the WM capacity, whereas their concept formation ability is. Hence, different from the study of Cepeda and Munakata (2007), perseverative behaviors in this study may be related to one's inhibition capacity rather than WM capacity, such that participant perseverates because s/he cannot inhibit the previously formed concept although s/he knows the correct rule or concept. However, a separate inhibition task is required in order to explore its relationship with the perseverative behavior.

The Relationship between Working Memory and General Fluid Intelligence

The present study suggests a significant relationship between WM capacity and *gf* with a moderate correlation ($r = .42$) between BDS and nonverbal CogAT® scores. In this regard, this study is in line with the previous research indicating a significant relationship between WM and *gf* (i.e., Conway et al., 2002; Engle et al., 1999; Fry & Hale, 1996).

General fluid intelligence basically refers to one's capacity to mentally process and use information appropriately in novel situations (Jensen, 2002; Yuan et al., 2006), and its relationship with WM and STM capacities has been investigated throughout the literature. In several studies, it is generally found that the relationship between STM and *gf* is not statistically significant while *gf* is significantly related with WM capacity after controlling for the variance due to STM capacity (Conway et al., 2002; Engle et al., 1999). For instance, in the study of Kyllolen and Christal, a latent variable analysis revealed that correlations between factors of WM capacity and fluid intelligence is about .80 to .90, which is a sufficiently high value for suggesting that WM capacity and fluid intelligence refer to the same construct (as cited in Engle et al., 1999). On the other hand, Engle et al. (1999) found that the correlation between factors of WM capacity and fluid intelligence is at the moderate level ($r = .49$) when the variability due to the STM capacity is excluded. Likewise, Fry and Hale (1996) reported a moderate level correlation ($r = .38$) between WM capacity and fluid intelligence after controlling for processing speed and age variables. In another study, Cowan and colleagues (2002) indicated a strong relationship between WM capacity and fluid intelligence (r = .60), but they stressed that WM and *gf* do not refer to identical capacities, rather they are highly correlated distinct constructs. In this regard, the moderate level correlation between BDS and the nonverbal CogAT® is a supporting evidence for the previous findings that WM capacity and general fluid intelligence are two separate, but significantly related constructs.

The Relationship between Executive Functions and General Fluid Intelligence

The relationship between EF and fluid intelligence is explored with respect to the correlation of nonverbal CogAT® with the WCST and the JBSRAT scores. Results indicate that as the participants' CogAT® scores increase, their concept formation scores increase (i.e., TC, CLR and CC scores of the WCST, and TC score of the JBSRAT); and scores indicating errors and poor conceptualization decrease (i.e., TE, NPE, and trials to complete first category in the WCST, and TE in the JBSRAT). Hence, present study suggests that *gf* is significantly related with the initial and following concept formations, and the maintenance of the concept appropriately throughout trials.

These findings provide further support for previous research suggesting that there is a significant relationship between intelligence and EF (i.e., Ardila et al., 2000; Arffa et al., 1998; Bielak et al., 2006; Friedman et al., 2006). Considering the WCST, there are some studies indicating a significant relationship of the test with IQ scores. For instance, Arffa et al. (1998) found that the full-scale IQ score of the

WISC-R is significantly correlated with WCST scores of TE, PE, NPE, and trials to complete first category. Likewise, Ardila et al. (2000) indicated a significant relationship between perseverative errors and IQ. Nevertheless, the present study does not claim a significant association between PE of the WCST and nonverbal CogAT®, but suggests that the concept formation scores of the WCST (i.e., TC, CC, CLR, NPE, and trials to complete first category) are significantly correlated with fluid intelligence. What is more, TC and TE scores of the JBSRAT are also associated with the nonverbal CogAT® score in the present study, supporting the study of Bielak et al. (2006), which revealed that the contribution of fluid intelligence to the performance in the Brixton Test is much more than the contribution of crystallized intelligence.

Demographic Variables and EF Performance

Present study focused on the effects of age, gender, grade, type of school, and mothers' education on measures of EF, WM, and fluid intelligence. Results can be summarized under 3 main points: (1) the main effects of age, grade, and type of school are not statistically significant for any of the WCST, JBSRAT, BDS, and nonverbal CogAT® scores; (2) the main effect of gender is statistically significant only for the JBSRAT; and (3) maternal education was found as a significant covariate not only for both EF measures, but also for the working memory measure.

Effects of Child and School Characteristics

Several developmental studies indicate that children's performance on EF measures increases as a function of age until about 10-11 years of age, and at this age period, children achieve an adult-level performance (Ardila et al., 2005; Bujoreanu & Willis, 2008; Chelune & Baer, 1986; Huizinga & van der Molen, 2007; Shallice et al., 2002; Shu et al., 2000). In this regard, it is consistently found that EF performance of children around 7 years of age is poorer than children about 10 years of age. For instance, the study of Bujoreanu and Willis (2008) comparing the WCST performances of three age groups (6-year-olds, 11-to12-year-olds, and 18-to19-year-olds) indicated that 6-year-olds displayed poorer performance on the number of categories they completed and learning efficiency than the other two age groups. Likewise, Shallice et al. (2002) found that 7- to 8-year-old children made more total and guessing errors than children with 9 to 12 years of age on the JBSRAT. On the other hand, present study did not reveal an age difference on EF performances, and this is in line with the findings of Yeniad (2009), which also indicated no differences between 6 and 7-year-olds with respect to their EF performances. This nonsignificant age effect may be related to the fact that the mean age difference between groups is small so that they do not differ on their PFC maturation, thereby in their EF performances.

Regarding the gender difference, findings of the present study are not consistent for both EF measures. It is found that performances of males and females do not differ for the WCST, the BDS, and the nonverbal CogAT®, whereas the gender difference is observed for total errors and perseveration scores of the JBSRAT. More specifically, females made more total errors and perseveration errors than males on the JBSRAT, but gender difference on perseveration is observed only for the 6-year-olds. In the 7-year-olds group, males and females did not differ on perseveration errors they made on the JBSRAT. Previous studies do not suggest a gender difference in EF performance (i.e., Ardila et al., 2005; Shu et al., 2000; Yeniçeri & Altan-Atalay, 2008; Yeniad, 2009), and present study supports this finding for the WCST, but not for the JBSRAT. Nevertheless, literature lacks studies on the JBSRAT regarding not only the gender difference, but also effects of other demographic variables (i.e., parents' level of education, or type of school). Hence, further studies should explore these effects on the JBSRAT performances of children.

Considering the effect of grade, performances of first and second graders did not differ on any of the measures in the present study. Likewise, the main effect of type of school was not significant for the test variables, and this is in line with the study of Ardila et al. (2005). In that study, effects of parental education and type of school on EF performance were explored via use of several EF measures including a Card Sorting Test, a simpler version of the WCST. It is found that although studying in a public or private school has an effect on EF performances of children, the group difference regarding the type of school was not observed for the Card Sorting Test (Ardila et al., 2005). Consequently, present study does not indicate any significant effect of grade and type of school on EF performance, and this may be related to the fact that two years in formal education may not be sufficient for observing the effects of grade and type of school on EF performance.

Effect of Maternal Education

Maternal education is a continuous variable that refers to years spent in education for mothers. It is used as a representative of parental education in the present study due to its high correlation with father education ($r = .83$) and less than one-year difference between means of maternal and father education. Regarding the maternal education, present study supports that it is a significant covariate not only for the EF measures, but also for the WM measure. More specifically, results suggest that maternal education is significantly related with (1) the WCST scores of total errors, NPE, CLR, and CC; (2) the JBSRAT scores of total errors, perseveration, and plausible errors; and (3) the BDS score. In this regard, present findings support previous studies indicating that parental education is significantly associated with EF performance (i.e., Ardila et al., 2005; Yeniçeri & Altan-Atalay, 2008), and WM (Yeniad, 2009).

Ardila et al. (2005) conducted a study investigating the effects of parental education on EF performance, and they found that parents' level of education is a significant covariate for the examined EF measures. Besides, Yeniçeri and Altan-Atalay (2008) stressed that maternal education significantly predicts perseveration scores of the WCST in a sample of 8- to 12-year-old children. On the other hand, present study indicates no significant association of maternal education with perseveration scores of the WCST, but with perseveration score of the JBSRAT. In this regard, these findings are in line with the study of Yeniad (2009) since the maternal education variable did not significantly predict the perseveration scores of the WCST, and partially related with the study of Yeniçeri and Altan-Atalay (2008) due to the fact that relationship of maternal education and perseveration is supported for the JBSRAT.

Researchers provide several explanations for the effect of maternal education on EF performance. For instance, it is argued that maternal education represents the richness of the child's intellectual environment that stimulates cognitive development of the child (as cited in Ardila et al., 2005). Additionally, Ardila et al. (2005) suggest that higher parental education may positively affect their children's language development, which is significantly related with better performance on cognitive measures. Higher education level is also considered as an indication of high socio-economic status (SES), which is expected to be associated with better education opportunities (i.e., private school education), and easier access to necessary sources (as cited in Ardila et al. 2005). Nevertheless, present study does not provide an explanation for the underlying dynamic of the relationship between maternal education and EF performance, but it is one of the studies supporting their significant relatedness.

Limitations and Future Directions

The main limitation of this study is that it has single measures of WM and fluid intelligence due to the time constraints of administration. In this regard, further studies should include several WM and fluid intelligence measures in order to obtain more comprehensive conclusions. Additionally, since the JBSRAT is a new task, further investigations on the JBSRAT are required with different clinical and non-clinical samples, with different EF measures, and for other age groups.

APPENDICES

APPENDIX A

Informed Consent Form

BİLGİLENDİRİLMİŞ OLUR FORMU

Sayın Veli,
Boğaziçi Üniversitesi Psikoloji Bölümü Yüksek Lisans 2. sınıf öğrencisi Nilay Şentürk tarafından hazırlanmakta olan "*7-8 Yaş Grubundaki Çocukların Küçük Brixton Testi ve Wisconsin Kart Eşleme Testindeki Performanslarının Belirlenmesi ve Küçük Brixton Testi'nin Güvenilirlik ve Geçerliğinin İncelenmesi*" konulu tez araştırmasına belirtilen yaşlardaki 1. ve 2. sınıf ilköğretim öğrencilerinin katılımı beklenmektedir. Söz konusu test bir kavramsal irdeleme ve dikkat ölçeğidir. Bu teste ilave olarak, işler bellek, dikkat ve hafızayı farklı açılardan ölçmek amacıyla "*Bilişsel Yetenekler Testi*" ve *"Sayı Dizisi"* testleri de uygulanacaktır.

Okul müdürlüğünün uygun bulduğu saatler içerisinde yürütülecek olan çalışmada test öğrencilere teker teker uygulanacaktır. Testin tamamlanması her çocukla yaklaşık 40 dakika (bir ders saati kadar) sürmektedir. Söz konusu ölçeklerin çocuklar üzerinde olumlu ya da olumsuz bir etkisi yoktur. Bu araştırma projesi Boğaziçi Üniversitesi Psikoloji Bölümü öğretim elemanlarının denetimi altında yürütülmektedir.

Çalışmaya katılacak tüm öğrencilerin kimlik bilgileri gizli tutulacaktır. Her katılımcı istediği an testi bırakma özgürlüğüne sahiptir. Araştırmaya yalnızca velisinin izni olan öğrencilerin alınacağını belirtir, çocuğunuzun katılımı için izninizi rica ederim.

Sorularınız için aşağıda belirtilen numaraları arayabilirsiniz.
Saygılarımla.

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Bu anlatılanları okudum ve anladım. Bilgilendirilmiş Olur Formu'nun bir örneğini aldım.

Velinin Adı Soyadı:
İmza:
Tarih:

APPENDIX B

Demographic Information Form

DEMOGRAFİK BİLGİ FORMU

ÇOCUĞUN ADI-SOYADI: ____
ÇOCUĞUN DOĞUM TARİHİ (gün / ay / yıl): ______________________________
VELİNİN YAKINLIK DERECESİ (anne, baba, vs.): __________________________
Annenin mesleğini yazınız: ____
Çalışıyor ise: Tam gün _____ / Yarım gün ______ / Kaç yıldır? ________

Annenin eğitim seviyesini işaretleyiniz:

a) Lisansüstü (Yüksek lisans ve/ veya doktora) mezun
b) Yüksek lisansın / doktoranın _____. sınıfından terk
c) Üniversite mezunu
d) Üniversitenin _____. sınıfından terk
e) Lise mezunu
f) Lisenin _____. sınıfından terk
g) İlköğretim mezunu (8 yıllık eğitim: ilkokul ve ortaokul)
h) İlkokul mezunu (5 yıllık eğitim)
i) İlköğretimin _____. sınıfından terk
j) Hiç okula gitmemiş ama okur-yazar
k) Hiç okula gitmemiş

Babanın mesleğini yazınız: ____
Çalışıyor ise: Tam gün _____ / Yarım gün ______ / Kaç yıldır? ________
Babanın eğitim seviyesini işaretleyiniz:

l) Lisansüstü (Yüksek lisans ve/ veya doktora) mezun
m) Yüksek lisansın / doktoranın _____. sınıfından terk
n) Üniversite mezunu
o) Üniversitenin _____. sınıfından terk
p) Lise mezunu
q) Lisenin _____. sınıfından terk
r) İlköğretim mezunu (8 yıllık eğitim: ilkokul ve ortaokul)
s) İlkokul mezunu (5 yıllık eğitim)
t) İlköğretimin _____. sınıfından terk
u) Hiç okula gitmemiş ama okur-yazar
v) Hiç okula gitmemiş

Evdeki çocuk sayısı kaçtır?: ________________
Çocuğunuz kardeşleri içinde kaçıncı çocuktur?
(İlk doğan çocuk (en büyük çocuk) 1. çocuktur. Buna göre çocuğunuzun kaçıncı çocuk olduğunu yazınız.) ____

Okul öncesi (1. sınıf öncesi) yuvaya / anaokuluna gitti mi? Gittiyse kaç yıl gitti?
____

Çocuğunuzun belirtmek istediğiniz bir sağlık sorunu (nörolojik ya da psikolojik tanısı) var mı? ____

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