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Hot and cool executive functioning and associations with social functioning in individuals with Schizophrenia Spectrum Disorders

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Abstract

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Supervisor I: Merete Glenne Øie; Supervisor II: Ingvild Haugen

Background: Executive functions (EF) are one of the most commonly impaired cognitive domains in individuals with schizophrenia spectrum disorders. In the last few decades, it has been increasingly apparent that the EF can be divided into an affective ("hot") dimension and a cognitive ("cool") dimension based on different brain networks and processes. There are few studies investigating both objective and subjective assessments of hot and cool EF in individuals with schizophrenia spectrum disorders. EF deficits are known to have a negative impact on a variety of functional outcomes such as social functioning. Schizophrenia is also frequently characterised by social functioning difficulties. Although the association between cool EF and social functioning is well established, the strength of the association between hot EF and social functioning is less known. The usage of multiple measures, as well as both objective and subjective assessments, may be beneficial to understanding the broader effect of EF on social functioning. The first aim of the current investigation is to investigate hot and cool EF using objective and subjective assessment in individuals with schizophrenia. The second aim is to investigate the associations between hot and cool EF and social functioning using both objective and subjective measures.

Methods: The present study used data from a study on Goal Management Training in participants with schizophrenia spectrum disorders and psychosis risk syndromes. Sixty-five participants with schizophrenia spectrum disorders were included in this cross-sectional study. The measures of objective cool EF were the Color-Word-Interference-Test 3, Color-Word-Interference-Test 4, Letter-Number Sequencing and Tower Test. The Iowa Gambling Task was used as a measure of objective hot EF. The Behavior Rating Inventory of Executive Function - Adult version was used to measure subjective hot and cool EF. Objective and subjective social functioning were measured with the Global Assessment of Functioning and the Social Functioning Scale, respectively. Results were analysed using linear regression analysis while controlling for presence of psychotic symptoms and the use of antipsychotic medication.

Results: The individuals with schizophrenia spectrum disorders demonstrated impairments in both hot and cool EF relative to norms. Objective cool EF was significantly positively associated with objective social functioning. Hot EF increased the explained variance of EF on objective social functioning. Moreover, objective hot EF was significantly negatively associated with objective social functioning. When including the presence of psychotic symptoms in the regression, the explained variance increased. Contrary to our assumptions, there was a lack of association between objective hot EF and subjective social functioning. Further, objective cool EF was associated with subjective social functioning, albeit in an unexpectedly negative direction. When including the presence of psychotic symptoms and the use of antipsychotic medication in the regression, the explained variance increased.

Conclusion: The current investigation proposes that individuals with schizophrenia have impairments on both hot and cool EF, indicating the possible benefits of targeting these aspects of EF in cognitive remediation. Interestingly, individuals with better objective cool EF have more self-reported social difficulties. Self-criticism, insight-related problems, and avoidance of negative occurrences may be possible explanations. Furthermore, those with better objective cool EF may be able to compare themselves to healthier individuals based on prior social relationships, whereas those with a lower objective cool EF may have less social experience and, as a result, a smaller basis for comparison. Although the inclusion of objective hot EF increased the explained variance of EF on objective social functioning, our results suggest that hot EF is not as important for impairments in social functioning as initially thought. Understanding the complexity of EF may also help enhance social functioning in individuals with schizophrenia.

Preface and acknowledgements

Since being introduced to psychopathology as a subject during our initial years of education, we have both taken a great interest in the field of schizophrenia. The disorder's complexity, multiple symptoms, and potential for remission, to name a few, piqued our interest and curiosity. Based on this, we decided to write the thesis together in order to explore the subject of schizophrenia more deeply. It has been a true honour to be allowed to participate in the ongoing research project Cognitive remediation of executive dysfunction - Goal Management Training (GMT) in individuals with schizophrenia or high risk for schizophrenia, which began in January 2017, as it is the first blinded, randomised controlled trial of GMT for individuals with broad schizophrenia spectrum disorders and psychosis risk syndromes. We are both grateful and consider ourselves fortunate to be a part of the project.

It has been a time-consuming, intense, and yet satisfying process. The process has also been a remarkable one from beginning to end, thanks mainly to our two knowledgeable and skilled supervisors. We would like to express our appreciation to our main supervisor and specialist in clinical neuropsychology, Merete Glenne Øie, for allowing us to use data for our cand.psychol. thesis and for trusting in us. Your professional knowledge, critical eye, and dedication have been contagious, and has also contributed to the project becoming even more meaningful. Without your accessibility and constructive feedback, the process would not have been as accomplishable. We would also like to thank our co-supervisor and psychologist, Ingvild Haugen. Your methodological expertise, optimistic attitude, and extensive feedback have undoubtedly helped make a seemingly massive project feel less overwhelming.

We would also like to express our gratitude to our families and friends for their support over the past year. Finally, we wish to thank each other for our friendship and for our cooperation throughout this time. We submit our cand.psychol. thesis with great pleasure and pride.

Oslo, October 2022

Markus Wilhelm Melseth Bergaust and Vincent Dahlgren Lima

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1 Introduction

1.1 Background

As an onerous and often chronic mental disorder, schizophrenia is frequently associated with impairment and disability (Volk et al., 2020). Schizophrenia is recognised as a substantial burden, firstly to the afflicted individual and their families, and secondly to society due to the high costs associated with the disorder (Millier et al., 2014).

Current pharmacological and psychosocial treatments focus primarily on clinical symptoms (Lehman et al., 2003; Barnes et al., 2020). In addition to the symptoms regarded as the diagnostic criteria of the condition (American Psychiatric Association, 2013), the evidence supporting the relationship between cognitive impairments and schizophrenia is strong and cognitive impairments are therefore considered a key feature of schizophrenia (Kahn & Keefe, 2013; Schaefer et al., 2013). Cognitive rehabilitation is increasingly recognised as a focus of treatment in schizophrenia, and the interest in these interventions is growing (Kahn et al., 2015; Ahmed, 2020). Cognitive remediation has been demonstrated to enhance daily functioning in individuals with schizophrenia (Vita et al., 2021). Having a better understanding of the specific cognitive domains associated with different aspects of functioning, can be important to determine which cognitive domains to target in cognitive rehabilitation.

Executive functioning is one of the most impaired cognitive domains in schizophrenia (Freedman & Brown, 2011; Orellana & Slachevsky, 2013; Green & Harvey, 2014). Executive functions (EF) can be viewed as a set of cognitive abilities and skills that enable us to exert deliberate control over our behavioural responses (Orellana & Slachevsky, 2013). EF are frequently described as an umbrella term that includes a vast array of cognitive processes that are essential for regulating, monitoring, and directing goal-oriented, conscious thought, action and emotion (Diamond, 2013; Goldstein et al., 2014; Zelazo, 2015; Poon, 2018). Due to these cognitive processes, humans are able to solve problems, create analogies, adapt to unforeseen circumstances, create and execute plans, perform multiple tasks simultaneously, distinguish between episodes in time/space, and adhere to social standards (Orellana & Slachevsky, 2013).

In recent decades, it has been increasingly apparent that the EF can be differentiated into an affective ("*hot*") and purely cognitive ("*cool*") dimension based on various brain networks and processes (Chan et al., 2008; Ward, 2020; Salehinejad et al., 2021). On the one hand, hot EF are characterised primarily by decision-making and delayed gratification, which are activated in circumstances where motivation and emotions are engaged. On the other hand, cool EF are engaged in emotion-neutral circumstances and are frequently characterised by cognitive processes such as inhibition, updating, and shifting (Biesmans et al., 2018; Zelazo, 2020; Salehinejad et al., 2021). This dichotomy has led to a new understanding of the concept of EF, with substantial clinical implications for the treatment of a variety of mental disorders (Snyder et al., 2015). However, this dichotomy has been the subject of few investigations in the realm of schizophrenia.

Further, several prior studies on schizophrenia only used a few measures to assess EF, and there is a major emphasis on measuring cool EF (Hwang et al., 2019). In addition, previous research in the field has been criticised for employing diverse evaluative measurements, making comparisons difficult because the studies frequently employ a small number of tests (Ruiz-Castañeda et al., 2020). There is limited research on both hot and cool EF in schizophrenia, as well as the association between them, in the same study (Poon, 2018; Woodrow et al., 2018; Hwang et al., 2019; Thai et al., 2019; Ruiz-Castañeda et al., 2020).

Although empirical data clearly supports the existence of executive dysfunction in individuals with schizophrenia, more knowledge is still sought about the relationship and patterns between executive functioning and aspects of everyday life (Iampietro et al., 2012). Clearly, executive functioning in schizophrenia is essential for daily functioning, and executive dysfunction has a significant influence on a variety of functional outcomes, including emotional, social, academic, occupational, and adaptive functioning (McGurk & Meltzer, 2000; Jurado & Rosselli, 2007; Lee et al., 2009; Tan, 2009; Hurtado et al., 2016; Velthorst et al., 2017; Macedo et al., 2018; Palsetia et al., 2018; Thai et al., 2019). In addition, it has been demonstrated repeatedly in the past that executive dysfunction is directly associated with a lower degree of life satisfaction (Herman, 2004; Ritsner, 2007; Savilla et al., 2008).

Schizophrenia is characterised by social functioning impairments (Hooley, 2010; Langdon et al., 2014). It is essential to figure out which elements can aid in the acquisition of social skills required for social functioning. Social relationships can be essential in alleviating symptom severity, as well as increasing the well-being and recovery rates in individuals with schizophrenia (Harvey et al., 2007; Schön et al., 2009; Harley et al., 2012; Vázquez Morejón et al., 2018).

Although the association between cool EF and social functioning is well established, the strength of the association between hot EF and social functioning is less known. Including hot EF may be of interest, as there is evidence for an association between increased social and emotional understanding and good performance on hot EF tasks (Garner & Waajid, 2012; Mann et al., 2016). Furthermore, the inclusion of multiple measures of objective and subjective hot and cool EF is rare in schizophrenia research and would be beneficial to understanding the broader effect of EF on social functioning.

This cand.psychol. thesis aims to investigate how individuals with schizophrenia spectrum disorders perform on neuropsychological tests measuring both hot and cool EF compared to norms. Furthermore, we also investigate the association between the hot and cool EF and social functioning. The subsequent chapters will firstly describe the characteristics and research on schizophrenia and cognitive impairment. Then, research focusing on hot and cool executive functioning will be elaborated on. Thereafter, research on social functioning in schizophrenia will be described, as well as the research on the association between social functioning and hot and cool EF in schizophrenia. Finally, the aims and hypothesis will be presented.

1.2 Schizophrenia spectrum disorders

1.2.1 Epidemiology and aetiology

The term "schizophrenia spectrum" appears frequently in the scientific literature, reflecting the heterogeneity of schizophrenia in its manifestation and aetiology as well as the difficulty in establishing diagnostic boundaries for schizophrenia-related illnesses (Spaulding et al., 2017). Schizophrenia spectrum disorders often consist of schizophrenia, schizoaffective disorder, schizophreniform episode, delusional disorder, and psychosis not otherwise specified (American Psychiatric Association, 2013). In this thesis, the term schizophrenia will be used to refer to disorders within the schizophrenia spectrum.

According to scientific consensus, around one percent of the world's population is affected by schizophrenia. A comprehensive study from Finland estimated the lifetime prevalence to be 0.87 percent (Perälä et al., 2007). The lifetime prevalence of schizophrenia spectrum disorders is believed to be 0.88 percent (Moreno-Küstner et al., 2018). Despite its presumed low frequency, schizophrenia causes significant economic, societal, and personal consequences worldwide. Traditionally, schizophrenia is characterised by an onset in early adulthood, particularly in men (Li et al., 2016). Studies have revealed a peak incidence between 20 and 24 years in men and between 29 and 32 years in women (Stilo & Murray, 2010). This debut of the psychotic illness in late adolescence or early adulthood may inflict personal burdens in the form of educational, occupational, and social consequences, limiting an individual's path to adulthood. Indirectly and directly, high unemployment rates and the cost of hospitalisation and treatment in chronic cases account for most of the economic burden (Crespo-Facorro et al., 2021).

Despite its lower prevalence, schizophrenia was ranked as the 12th most disabling disorder in a 2016 evaluation of the global burden of disease (Charlson et al., 2018). The life expectancy of individuals with schizophrenia is predicted to be 10 to 20 years less than that of the general population, and is frequently associated with cardiovascular disease and diabetes (Laursen, 2011; Moradi et al., 2018). Individuals with schizophrenia have a lifetime suicide rate of 4.9%, and suicidal ideation, self-harm, and suicide attempts are prevalent (Palmer et al., 2005; Meltzer, 2006; Björkenstam et al., 2014).

Schizophrenia does not have a clearly defined aetiology, however over the years of research various theories have emerged. Numerous links between schizophrenia and abnormal brain development, genetics, and the environment have been the subject of extensive investigation. The disease's heterogeneity has substantially complicated the task of discovering aetiological variables (Onaolapo & Onaolapo, 2018). There is evidence for the existence of genes that increase the chance of developing schizophrenia and evidence for its high heritability (Harrison, 2014). However, genetic factors alone cannot sufficiently describe the disorder (Torrey & Yolken, 2019). Environmental factors, such as prenatal and perinatal complications, stressors, drug use, migration, and urbanisation, have been suggested to contribute to the development of schizophrenia (Onaolapo & Onaolapo, 2018).

Imbalances in neurotransmitters, and most notably in dopamine, has been one of the most important aetiologic theories in schizophrenia. The dopamine-hypothesis is in part supported by the evidence of the therapeutic effect of antipsychotic medication, and the correlation between the effect and the scale of dopamine-receptor blockade (Kendler & Schaffner, 2011). Antipsychotic medication is considered a cornerstone in treatment of schizophrenia (Lally & MacCabe, 2015). Functional and structural abnormalities are prominent in individuals with schizophrenia (Karlsgodt et al., 2010). Using imaging technology (functional magnetic resonance imaging and magnetic resonance imaging, respectively), the scientific community has reached a consensus on lower activity in the prefrontal cortex, also known as hypofrontality, as well as indications of volume reduction in various brain regions, among individuals with schizophrenia (Pratt et al., 2008; Garlinghouse et al., 2010; Haijma et al., 2013). Functional and structural abnormalities in the prefrontal cortex are frequently associated with deficits in EF (Jones & Graff-Radford, 2021).

Schizophrenia is often conceptualised as either a neurodegenerative disorder or a neurodevelopmental disorder. The neurodegenerative model for schizophrenia considers the disorder the result of progressive deterioration, also resulting in progressive cognitive deterioration (Jonas et al., 2022). The neurodevelopmental model considers the disorder to emerge as a result of abnormal brain development, and to end in psychosis. This model implies that the manifestation of the disorder is detectable long before psychosis onset and implies the stabilisation of cognitive deficits after onset. Longitudinal studies have supported the neurodevelopmental model, with evidence of cognitive decline and abnormal brain development long before illness onset and stability after psychosis onset (Weinberger & Levitt, 2011; Melle, 2019; Jonas et al., 2022).

Additionally, studies do not find associations between cognitive deficits and variation in duration of untreated psychosis, indicating the stagnation of cognitive deterioration after the onset of psychosis (Melle, 2019). The neurodevelopmental model also implies the hypothesis of a shared liability between cognitive deficits and psychosis. However, this correlation is probably modest, and the direction of the correlation is unknown. As such, the causality between cognitive deficits and the development of schizophrenia can go both ways (Reichenberg et al., 2019). Although with some aetiological limitations, the neurodevelopmental model is considered one of the most well-established theories explaining the aetiology of schizophrenia (Andreasen, 2010; Insel, 2010; Rapoport et al., 2012; Øie et al., 2021).

1.2.2 Symptoms

Schizophrenia is a disorder recognised by a broad collection of symptoms and characteristics (Tandon et al, 2009). Positive symptoms, negative symptoms, and cognitive impairments are typically included in a trichotomy that depicts the vast array of symptoms and traits. The cognitive impairment category, which will be examined in depth later in this chapter, is recognised as a core characteristic of individuals with schizophrenia and not as a symptom and diagnostic criterion (Kahn & Keefe, 2013).

Positive symptoms are hallucinations, delusions, and thought disorders, that alter the normal state of perception and interpretation of the world (Fletcher & Frith, 2009; Hinzen & Rosselló, 2015). These positive symptoms typically attract the most clinical attention and are often the reason individuals with schizophrenia and caregivers seek help in the first place (McCutcheon et al., 2019). However, negative symptoms and cognitive impairments account for a larger part of the functional deterioration and the long-term morbidity (Buchanan, 2007). Negative symptoms include anhedonia, lack of motivation, social withdrawal, lack of motor and mimical abilities, poverty of speech, affective incongruence and alogia (Kirkpatrick et al., 2006; Harvey et al., 2019). Individuals with schizophrenia often have comorbid disorders, with substance abuse, depression and anxiety disorders being the most frequent (Buckley et al., 2008).

1.2.3 Cognitive impairments

Cognitive impairments are widely regarded as a core characteristic in schizophrenia. Several reviews emphasise the significant evidence of there being a general neurocognitive deficit in individuals with schizophrenia compared to healthy controls (Schaefer et al, 2013; Green et al., 2019; East-Richard et al., 2020). Neurocognitive impairments were present in both older samples with chronically ill individuals and in first episode individuals, supporting the claim that the deficits are not solely explained by illness chronicity and medication/treatment (Kurtz, 2005; Mesholam-Gately et al., 2009, Keefe & Harvey, 2012).

There is evidence of global neurocognitive deficits in the premorbid and prodromal stages of the illness, but the deficits are substantially smaller than those reported after the onset of the illness (Brewer et al., 2006; Woodberry et al., 2008; Mesholam-Gately et al., 2009). In addition, mild neurocognitive abnormalities are apparent in unaffected relatives of individuals with schizophrenia and in individuals with Clinical High Risk for psychosis (Snitz et al., 2006; Catalan et al., 2021). This accentuates the fact that neurocognitive impairments are thought of as a general vulnerability preceding illness onset and not caused by symptoms (Reichenberg, 2005).

Compared to their expected cognitive ability in the absence of the disorder, nearly every individual with schizophrenia experiences neurocognitive deficits (Keefe & Harvey, 2012). According to a study, 98% of individuals with schizophrenia showed worse neurocognitive functioning when compared to their intellectual potential as predicted by maternal education (Kahn & Keefe, 2013). Another study found that neurocognitive deficits are present in individuals with schizophrenia with superior, normal, and low intellectual functioning, compared to healthy controls with the same intellectual ability (Vaskinn et al., 2014). On neurocognitive tasks, individuals with schizophrenia perform between 1.5 and 2 standard deviations below healthy controls. However, some studies found that up to 20% of the individuals with schizophrenia did not have any significant impairments if impairment is defined as being one standard deviation below the mean of healthy controls (Keefe & Fenton, 2007; Kahn & Keefe, 2013). Another study found that if the impairment was defined as below 1.5 standard deviations below, an estimated 35 to 40% did not show significant impairment (Rund et al., 2006).

Neurocognitive impairments are relatively unrelated to positive symptoms (Keefe & Harvey, 2012; Strassnig et al., 2015). The association between negative symptoms and neurocognitive deficits has been discussed (Galderisi et al., 2018). Studies have demonstrated a low to modest correlation between negative symptoms and neurocognitive dysfunction (Harvey et al., 2005). Some studies have demonstrated correlations between certain neurocognitive functions (EF and verbal fluency) and certain negative symptoms (avolition and alogia) (Marder & Galderisi, 2017). However, others suggest that no neurocognitive functions stand out as particularly associated with negative symptoms (Harvey et al., 2005). Negative symptoms and neurocognitive impairments both have substantial negative effects on daily functioning (Galderisi et al., 2018). However, the overall association between neurocognitive impairments and negative symptoms remains quite moderate, and it has been hypothesised that their shared characteristics may in fact explain their association with functional outcomes (Foussias et al., 2014).

In schizophrenia, neurocognitive impairments appear to be relatively stable across time, even though individuals with schizophrenia have substantial impairments. Onset age, initial impairment and chronicity does not appear to affect the cognitive trajectory (Heaton et al., 2001).

As a group, individuals with schizophrenia experience a global neurocognitive impairment (Schaefer et al., 2013). However, some studies suggest specific impairments in certain domains, such as attention/processing speed, visual memory and verbal memory, and EF (Johnson-Selfridge & Zalewski, 2001; Reichenberg et al., 2009; Holmen et al., 2010; Knowles et al., 2010; Reichenberg et al., 2010; Schaefer et al., 2013).

Some claim that deficits in EF are the most prevalent neurocognitive impairment in schizophrenia (Raffard & Bayard, 2012; Orellana & Slachevsky, 2013; Aas et al., 2014; Thai et al., 2019). According to a recent review, deficits in executive functioning is one of the most reported and severe neurocognitive deficits across all psychological disorders. In addition, individuals with schizophrenia are the group most affected by deficits in EF (East-Richard et al., 2020).

1.3 Executive functioning

The majority of previous studies on EF originate from neuropsychological research on individuals with frontal lobe injury (Stuss & Benson, 1986). There is conclusive evidence that lesions in the prefrontal cortex impair performance on tasks requiring impulse control, working memory, strategic planning and behavioural inhibition (Tanji & Hoshi, 2001; Curtis & D’Esposito, 2003; Knutson et al., 2015; Li et al., 2020). With the rise of technology, it has been determined that EF are composed of several neural networks, which include frontal and posterior regions of the cerebral cortex, along with subcortical regions (Marvel & Desmond, 2010; Salehinejad et al., 2021; Friedman & Robbins, 2022).

Despite substantial agreement on the several facets of EF, there is a lack of consensus regarding its definition (Jurado & Rosselli, 2007; Thai et al., 2019). In the absence of a comprehensive definition that fully encompasses the conceptual scope of EF, it could be described as the collection of higher-order cognitive processes that enable an individual to thrive and adapt in complex psychosocial contexts (Delis, 2012). The development of EF begins during infancy and continues to develop throughout early childhood, adolescence and young adulthood in both complexity and capability (Zelazo et al., 2003). The various components tend to evolve in response to environmental situations and conditions and appear to mature and reach their peak during young adulthood (Huizinga et al., 2006; Ferguson et al., 2021).

Throughout the recent decades, there has been a growing consensus that cognitive abilities and processes such as attention shifting, inhibitory control, working memory, strategic planning and goal-oriented behaviours are essential components of EF (Barkley, 1997; Miyake et al., 2000; Zelazo & Müller, 2002; Goldstein et al., 2014; Friedman & Robbins, 2022). Based on a systematic analysis of 106 recent empirical investigations, the most frequently examined components of EF are inhibitory control/response inhibition ("*Inhibition*"), updating and monitoring of working memory ("*Updating*"), mental set shifting/cognitive flexibility ("*Shifting*") (Baggetta & Alexander, 2016). Additionally, *planning* is frequently mentioned. Based on this consensus, these components will serve as a basis of cool EF in this thesis.

Frequently, *inhibition* is defined as a person´s ability to intentionally control or inhibit automatic or dominating responses, thoughts, or behaviours (Mäntylä et al., 2010; Causse et al., 2011). *Updating* is the ability to hold an idea or task in one's mind while swiftly adding or eliminating information, depending on the demands of the task (Miyake et al., 2000). *Shifting* can be characterised as the flexible capacity to transition between tasks, perspectives, or mental sets, and can be regarded as the opposite of rigidity (Miyake et al., 2000; Diamond, 2013). *Planning* is often characterised as the capacity to develop mental representations of a problem in order to identify the most appropriate solution. The extent to which an individual can anticipate the outcomes of two or more moves prior to their execution is frequently used to assess his or her planning skills (Delis et al., 2001; Morris & Ward, 2005).

Based on prior research and literature, a less controversial way of organising the term executive functioning is to make the distinction of an affective (*Hot*) dimension and solely cognitive (*Cool*) dimension (Chan et al., 2008; Zelazo & Carlson, 2012; McDonald, 2013; Ward, 2020). *Hot* EF are frequently defined as goal-oriented, top-down cognitive processes prompted by contexts that evoke motivation, emotion and desire (Zelazo et al., 2005; Chan et al., 2008). Hot EF can be understood as the self-management and problem-solving skills we deploy in motivationally and emotionally charged situations in response to self-relevant, meaningful rewards or punishments (Zelazo & Müller, 2002; Hongwanishkul et al., 2005). Essentially, several researchers associate hot EF with social and emotional processing, the domain of self and social understanding, and "social executive functioning" (Happaney et al., 2004; Hongwanishkul et al., 2005; Zelazo et al., 2005; Beer, 2006). Common examples of hot executive functioning are risky/affective *decision-making* and delayed gratification (Bechara et al. 1999; Zelazo & Carlson, 2012; Roiser & Sahakian, 2013; Salehinejad et al., 2021).

Decision-making can be defined as the process when an individual makes a choice after reflecting on the consequences of that choice (Bechara & van der Linden, 2005). To provide an explanation for impairment of *decision-making* in individuals with ventromedial prefrontal cortex damages, the “somatic marker hypothesis” was developed (Damasio et al., 1991; Bechara & Damasio, 2005). The hypothesis described the significance of emotions in the future *decision-making* process and how previous positive or negative emotion-based representations ("somatic markers") influence future-oriented decisions. Insufficient activation of these "somatic markers" is regarded as the cause of poor *decision-making* (Damasio et al., 1991; Bechara et al., 2000). The Iowa Gambling Task (IGT; Bechara et al., 1994) was designed to test the somatic marker hypothesis and is regarded as one of the most appropriate experimental measures of ambiguous and risky *decision-making*. The first part of the psychological task is presumed to be the ambiguous phase, which is characterised by a predominance of implicit information and understanding that guides our decisions, whereas the second and final part, the risky phase, is characterised by explicit information, as participants' conceptual understanding of the task's framework and contingencies increases (Maia & McClelland, 2004; Brand et al., 2007; Persaud et al., 2007; Guillaume et al., 2009; Buelow & Blaine, 2015; Stratta et al., 2015). IGT's consideration of uncertainty, incentive, and punishment resembles two sorts of decisions that permeate everyday life. The ability to make consistent, appropriate decisions during the risky phase is contingent on the outcomes of decisions made during the ambiguous phase. A defining characteristic of this task is that participants must forego short-term gains in favour of long-term profit by adhering to the test's contingencies and determining which card decks are profitable over the long term (Dunn et al., 2006).

In contrast, *cool* EF are goal-oriented, top-down cognitive skills that do not involve emotional arousal, but are instead "logical" and "mechanical" in nature (Chan et al., 2008; Zelazo & Carlson, 2012). The traditional understanding of executive functioning, in which emotions play no role, has been labelled cool EF (Poon, 2018). As stated previously, inhibition, updating, and shifting are typical examples of cool EF that manifest under relatively structured and analytic test conditions (Miyake et al., 2000; Biesmans et al., 2018).

1.3.1 Objective and subjective "hot" and "cool" EF in schizophrenia

In the present thesis both objective and subjective measures of EF were used. *Objective* EF measures refer to formal neuropsychological tests. *Subjective* EF measures refer to self-report assessments and questionnaires. These two types of EF measures are thought to complement each other, to get a complete understanding of EF in individuals with schizophrenia (Bulzacka et al., 2013).

1.3.1.1 Objective measures of hot and cool EF

A meta-analysis based on *objective hot EF* indicated that individuals with schizophrenia made more unfavourable decisions than healthy controls, such as drawing cards from unfavourable decks during IGT. The researchers interpreted that deficiencies in reinforced learning could account for the poor performance of individuals with schizophrenia on gambling tasks (Brown et al., 2015). A more extensive meta-analysis revealed similar findings (Betz et al., 2018). In contrast to individuals with schizophrenia, who did not display a learning curve beyond assessment, healthy controls made frequent profit-maximising decisions and demonstrated a steep learning curve. The researchers hypothesise that the impairment in risky, reward-based *decision-making* in schizophrenia may be associated with cognitive dysfunction, such as reduced working memory/*updating*. Moreover, individuals with schizophrenia frequently make more irrational decisions than healthy controls in social decision-making tasks involving other participants, accepting significantly more unfavourable offers and rejecting more favourable ones (Yang et al., 2017).

Data from measures of *objective cool EF* have dominated the majority of previous research on executive functioning and schizophrenia (e.g., Jogems-Kosterman et al., 2001; Henik et al., 2002; Hartman et al., 2003; Clark et al., 2010; Westerhausen et al., 2011). According to a recently published, highly comprehensive meta-analysis, deficits in objective cool executive functioning among individuals with schizophrenia have a large effect size (d = 0.85). In addition to deficits in neuropsychological subdomains, such as fluency, verbal and non-verbal memory, processing speed, attention, and visuospatial function, there are clear indications that response inhibition (*Inhibition*), working memory (*Updating*), and set shifting (*Shifting*) are significantly impaired among individuals with schizophrenia (Abramovitch et al., 2021).

Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) is one of the most extensively used performance-based, cool EF test batteries (Stephens, 2014). Prior research indicates that there are significant differences between healthy controls and those with schizophrenia on all of the D-KEFS subtests, where the individuals with schizophrenia generally performed worse (Savla et al., 2011). On subtests measuring *mental planning* (Tower Test) and *inhibition* and *inhibition/shifting* (Color-Word Interference), the effect size ranges from medium to large. The Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler, 2008) is another test battery that has been extensively applied for decades to assess the cognitive abilities and impairments of individuals with schizophrenia. Cognitive areas such as processing speed and *updating* are consistently impaired and sensitive in the population with schizophrenia (Michel et al., 2013). Extensive research indicates that individuals with schizophrenia perform worse compared to healthy controls on the majority of WAIS tasks (Gold et al., 1995; Allen et al., 1998; Revheim et al., 2006; Michel et al., 2013; Fuentes-Durá et al., 2019). In a comprehensive study, it was discovered that individuals with schizophrenia performed worse than healthy controls on a subtest of the WAIS measuring verbal working memory/*updating* (Letter-Number Sequencing) (Lee et al., 2015). In addition, there is evidence that individuals with schizophrenia consistently perform worse on *updating* than either first-degree relatives or healthy controls (Botero et al., 2013). A meta-analysis of first-episode individuals with schizophrenia revealed that, despite individual variances, the participants had impaired cognitive functioning compared to healthy controls. The findings indicate impaired general cognitive abilities and working memory/*updating* (Mesholam-Gately et al., 2009; Freedman & Brown, 2011).

Despite the fact that diverse psychosis groups score worse than healthy controls on several cool executive function tests, there are indications that individuals with schizophrenia perform worse on a wide variety of executive tasks than individuals with other psychotic illnesses (Zanelli et al., 2010; Freedman & Brown, 2011). According to a meta-analysis that focused solely on cognitive flexibility, there are clear indications that individuals with schizophrenia exhibit poorer performance in domains such as processing speed and *shifting* (Laere et al., 2018). Evidence suggests that difficulties with *shifting* in individuals with schizophrenia may be the basis for deficits in more complex EF tasks (Snyder et al., 2015).

A meta-analysis revealed a medium-to-large effect size (d = 0.67) confirming the long-held notion that individuals with schizophrenia have impaired *planning* ability (Knapp et al., 2017).

1.3.1.2 Subjective measures of hot and cool EF

Subjective assessments (self-reported) are important because they give information about EF as the individual experiences it in real-world situations, whereas more objective and structured assessments do not. There are several subjective measures of EF, and one of most frequently used is the Behavior Rating Inventory of Executive Function - Adult version (BRIEF-A; Roth et al., 2005) which has measures of both hot and cool EF (Egeland & Fallmyr, 2010). The BRIEF-A can be used as a measure for ecological validity. It can also be used to gain a better understanding of each individual's specific and subjective challenges with executive functioning in daily life (Isquith et al., 2006). Subjective measures of executive functioning have been utilised infrequently in disorders with more severe psychopathology, such as schizophrenia, possibly due to concerns that individuals with schizophrenia may lack insight into cognitive difficulties (Burton et al., 2011; Bulzacka et al., 2013). Research has suggested that individuals with schizophrenia may not identify their own difficulties in EF, even though they show deficits on objective tasks and observations (Harvey & Pinkham, 2015). However, studies have demonstrated that individuals with schizophrenia report significantly greater difficulty with their daily executive performance abilities, measured with the BRIEF-A, than healthy controls (Bulzacka et al., 2013; Haugen et al., 2021). The difficulties were linked to both hot and cool executive functioning areas. Individuals with schizophrenia reported the most difficulty adjusting to routine changes (*shifting*) and utilising their working memory/*updating* (Kumbhani et al., 2010). Similar findings have been replicated, indicating that individuals with schizophrenia consistently report difficulty on both hot and cool executive domains compared to healthy controls (Bulzacka et al., 2013).

Based on previous research, there is substantial evidence for impairment on both objective and subjective cool EF in individuals with schizophrenia compared to healthy controls. However, there is less evidence for impairment on both objective and subjective hot EF. Additionally, few EF measures have been used in the same study. A broad use of multiple and diverse EF assessments, including objective and subjective measures of EF in the same study, may be valuable for a thorough understanding of EF impairments in schizophrenia.

1.4 Social functioning in schizophrenia

Although it is widely acknowledged that deficits in social functioning are a core characteristic in schizophrenia, there are difficulties in establishing a consensus definition (Burns & Patrick, 2007; Velthorst et al., 2017). In DSM-IV and DSM-V, social functioning deficits are a diagnostic criterion for schizophrenia, and encompass deficits in three domains: occupational functioning, interpersonal functioning, and self-care (American Psychiatric Association, 2000; 2013). Social functioning has been defined as the individual's ability to fulfil society-defined roles (as a spouse, student, friend, family member, or worker); their own satisfaction with their ability to fulfil these roles; their capacity for self-care; and the scope of their recreational activities (Mueser & Tarrier, 1998; Burns & Patrick, 2007). These facets of this description of social functioning can be reorganised into a dichotomy of objective and subjective perspectives of social functioning. In addition, a review indicated that the Global Assessment of Functioning (GAF) scale (Goldman et al. 1992) and the Social Functioning Scale (SFS) (Birchwood et al., 1990) are the two most commonly used assessments for social functioning in schizophrenia today (Burns & Patrick, 2007). The GAF is a global measure of occupational, psychological and social functioning (Goldman et al., 1992). The SFS contains several more specific domains of daily and social functioning (Birchwood et al., 1990). In this instance, the objective/subjective dichotomy is clear, since the GAF is evaluated and scored by a clinician, whereas the SFS is a self-reported questionnaire. These two measurements are used in this present study and will therefore be discussed in further depth in the next chapter.

Negative and positive symptoms are related to social dysfunction, although they are regarded as separate entities. However, signs of social dysfunction are not always easily distinguishable from negative symptoms, as these symptoms often lead to social isolation (Burns & Patrick, 2007).

Stable, long-term impairments in social functioning in those suffering from schizophrenia have been demonstrated, most notably in a 20-year longitudinal study (Velthorst et al., 2017). Deficits in social functioning have also been considered a risk factor for psychosis and are present prior to the onset of the illness (Cornblatt et al., 2012). These findings, along with the inclusion of social dysfunction in the diagnostic criteria, indicate that social dysfunction is a basic feature of schizophrenia (American Psychiatric Association, 2000; 2013).

A concept that can be linked to social and executive functioning in schizophrenia is social cognition. Since social cognition is not assessed in the present investigation, only a brief description will be provided. Social cognition refers to the mental functions required for successfully managing social situations. The term comprises the capacities to receive, interpret, and process information necessary for adapting to various contexts (Green et al., 2019). Identifying and interpreting the emotions and intentions of others and using this information to adapt and behave also fall under social cognition. As the field of social cognition and its measures have only arisen in the last decade, the prevalence of social cognition impairments in schizophrenia is relatively new (Silberstein & Harvey, 2019). There is conclusive evidence, according to a recent meta-analysis, that individuals with schizophrenia exhibit impairments in a range of social cognition domains (Weinreb et al., 2022). Social cognition is thought to be a mediator between neurocognition and real-world functioning, in schizophrenia (Kharawala et al., 2021). Furthermore, a study suggested that social cognition was a component of hot EF (Baez & Ibanez, 2014). Another study recognised social cognition as being a hot EF component and subdivided it into hot and cool aspects within the hot domain (McDonald, 2013).

1.4.1 The association between hot and cool EF and social functioning

Several studies demonstrate that individuals with schizophrenia often experience difficulties in social functioning (Langdon et al., 2014; Dodell-Feder et al., 2015). A positive association has been shown between sustained attention and cool EF abilities like sequencing (*updating*) and communication ability (Docherty, 2005). In addition, decreased attention, lower global intellectual functioning, and impaired EF, are associated with poorer interpersonal problem-solving skills in individuals with chronic, long-lasting schizophrenia (Zanello et al., 2006). A study also shows an association between poor performance on objective cool EF tasks measuring *shifting* and low subjective empathy scores (Shamay-Tsoory et al., 2007). Moreover, deficits in working memory/*updating* greatly impair the capacity to acquire, maintain, or relearn abilities that are crucial for real-world functioning, such as forming relationships and sustaining employment (Lasser et al., 2007; Lepage et al., 2014).

Individuals with "somatic marker network" lesions exhibited impaired risky *decision-making*, social dysfunction, and low emotional intelligence, according to research (Bar-On et al., 2003). Furthermore, a significant and substantial positive correlation between risky *decision-making* and occupational functioning has been demonstrated in schizophrenia, indicating that impaired hot EF components can affect social outcomes with fewer social interactions, less participation in community activities, and reduced work skills (Stratta et al., 2015). These findings may imply that hot EF is important for social functioning in people with schizophrenia.

Metacognitive deficiencies, strongly related to EF, are frequently observed in individuals with schizophrenia, and they are thought to be predictive of social functioning difficulties (Roebers, 2017; Lysaker et al., 2019). Metacognition can be characterised as a set of processes that include the formation of concepts about feelings and thoughts, as well as the integration of these feelings and thoughts into complex representations of others and oneself (Lysaker et al., 2013). Further, a link between poorer metacognition and reduced social functioning in schizophrenia has been found (Massé & Lecomte, 2015). This may highlight the significance of metacognition and its relation to EF for social functioning in schizophrenia.

A study that examined metacognitive capacities in four groups of individuals with schizophrenia based on their social functioning and symptomatology found that the groups with the poorest social functioning and predominantly negative symptoms had lower levels of metacognition (Gagen et al., 2019). An objective measure, the Metacognition Assessment Scale–Abbreviated (Lysaker et al., 2005), was used to assess metacognition. Two subscales of The Quality of Life Scale (Heinrichs et al., 1984), the Interpersonal and the Intrapsychic subscales, were thought to reflect social functioning. These subscales are assessed with semi-structured interviews, rated by a clinician, and can therefore be regarded as an objective measurement of social functioning.

A recent study found an association between performance on tasks requiring problem-solving and *planning* skills and social engagements in adolescents with schizophrenia, suggesting that impairments in aspects of cool executive functioning may account for the difficulties in social engagement in individuals with schizophrenia (Madjar et al., 2019).

In a meta-review on schizophrenia, a significant positive correlation was discovered between numerous neurocognitive domains, including cool EF measures, and better community functioning. Community functioning encompasses a variety of general behaviours of daily functioning, such as social relations, self-management, and self-care (Najas-Garcia et al., 2018).

Based on previous studies, there are indications of a positive association between EF and social functioning in schizophrenia. Cool EF measures have been the predominant method for investigating these associations. No studies have, as far as we know, previously investigated the association between objective and subjective measures of both hot and cool EF and social functioning in the field of schizophrenia research. Including the hot aspect of EF may help explain the variance of social functioning or reveal information about which components that are associated with difficulties in social functioning. Furthermore, this information may, in the longer term, be useful for improving social functions.

There are indications that the presence of symptoms can predict community functioning in schizophrenia and that antipsychotic medication use is associated with a decrease in self-reported daily functioning in schizophrenia (Norman et al., 1999; Tandon et al., 2020). Although positive symptoms do not appear to be related to EF, small to moderate correlations have been identified between the presence of negative and disorganised symptoms and EF in individuals with schizophrenia in stable illness-stages (Greenwood et al., 2008; Dibben et al., 2009; Suttajit et al., 2015). Therefore, controlling for presence of symptoms may be relevant in this study. A recent meta-analysis indicated significant positive effects of several antipsychotics on cognition. However, a uniform effect of antipsychotic medications on cognition was not discovered, and the effect varied across cognitive domains (Baldez et al., 2021). Controlling for the possible effect of antipsychotic medication on the relationship between EF and social functioning is relevant in light of recent findings indicating a possible effect of some antipsychotics on cognition, despite widespread agreement that the effect of antipsychotic medication on cognition in individuals with schizophrenia is rather modest. (Nielsen et al., 2015).

1.5 Aims and hypotheses

The first main aim of the current cand.psychol. thesis is to investigate hot and cool EF measured with both objective and subjective measures in individuals with schizophrenia. We hypothesise that individuals with schizophrenia spectrum disorders have impairments in both hot and cool EF tasks, as well as in objective and subjective measures relative to norms.

The secondary main aim is to investigate the associations between hot and cool EF, using both objective and subjective measures, and social functioning, using both objective (GAF) and subjective (SFS) measures. Regarding the second aim, we controlled for the presence of symptoms and the use of antipsychotic medication. We hypothesise, based on prior research, that including measures of hot EF would increase the explained variance of EF on both subjective and objective measures of social functioning.

2 Methods

The current study builds on a selected sample of participants from Haugen, Øie and colleagues' (2022) randomised controlled trial; a project titled "Cognitive remediation of executive dysfunction - Goal Management Training for patients with schizophrenia or high risk for schizophrenia" that examined the effects of Goal Management Training (GMT) on executive function. The project was financed by South-Eastern Norway Health Authority (grant number 2017012), Innlandet Hospital Trust (grant number 150602) and the University of Oslo (grant number 353139). Trial registration number: NCT03048695, 09/02/2017: clinicaltrials.gov. The initial sample included 81 individuals diagnosed with schizophrenia spectrum disorders and psychosis risk syndromes (Haugen et al., 2022). In the present study, baseline data from participants with schizophrenia spectrum disorders were analysed, excluding data from participants at risk of psychosis to keep the thesis focused and concise, as well as to limit the heterogeneity in the sample to improve the generalisability. All measures of EF and social functioning used in the project were included in the present study.

2.1 Participants

The sample consisted of 65 individuals with broad schizophrenia spectrum disorders who were referred to Innlandet Hospital in Norway for treatment of their psychosis between 2017 and 2020. Table 1 provides a more detailed overview of the sample's demographic and clinical features.

Participants were diagnosed with a schizophrenia spectrum disorder using the DSM-IV criteria as an inclusion criterion when the study began in 2017 (Diagnostic and Statistical Manual of Mental Disorders - IV - Text Revision) (American Psychiatric Association, 2000). SCID-I (Structured Clinical Interview for the DSM-IV, Axis 1 disorders) was used to conduct the diagnostic examination. SCID-I is a semi-structured clinical interview designed to be consistent with the DSM-IV Axis 1 diagnostic criteria for psychiatric disorders (First & Gibbon, 2004; Gorgens, 2011).

The participants had to be between the ages of 16 and 67. The individuals enrolled in this study, ranged from 16 to 44 years old, and had a mean age of 25 years (SD = 6,53). The sample consisted of 26 females (40%) and 39 males (60%). Since previous research has suggested that men tend to develop schizophrenia at a younger age, this may be a representative sample for individuals seeking treatment from early intervention clinics (Li et al., 2016).

Additionally, the BRIEF-A *t*-scores served as an inclusion criterion for the GMT project (Haugen et al., 2022), from which this study is derived. A BRIEF-A Global Executive Composite *t*-score of greater than 55 was required. According to studies, healthy individuals in Norway have lower *t*-scores than healthy individuals in the United States. Thus, *t*-scores more than 55 can be considered as clinically significant scores (Løvstad et al., 2016).

Severe intellectual disability (IQ<70), premorbid and/or comorbid neurological illnesses, current alcohol or substance abuse, or treatment for psychosis for a period of more than five years were all considered exclusion criteria.

Table 1. *Demographic and clinical overview of the sample (n=65)*

Participant characteristics	*Frequency*	*Mean*	*SD*	*SE*
Age		25.42	6.53	0.81
Gender				
Female	26 (40.00%)			
Male	39 (60.00%)			
Education (in years)		12.86	1.81	0.23
Estimated IQ		98.03	13.97	1.80
Employment				
Full-time work/study	12 (18.50%)			
Part-time work/study	9 (13.80%)			
Supported employment	14 (21.50%)			
Not working/studying	30 (46.20%)			
Living arrangements				
Alone	21 (32.30%)			
With partner and/or children	11 (16.90%)			
With parent	18 (27.70%)			
With friends/ in shared house	2 (3.10%)			
In supported housing	13 (16.00%)			
In a relationship	13 (20.00%)			
Diagnosis				
Schizophrenia	29 (44.60%)			
Schizoaffective disorder	14 (21.50%)			
Schizophreniform disorder	6 (9.20%)			
Psychotic disorder NOS	15 (23.10%)			
Delusional disorder	1 (1.50%)			
Duration of untreated psychosis (weeks)		241.18	244.01	30.27
Symptoms of psychosis (PANSS)				
Positive (total of 7 items)		18.26	4.07	0.50
Negative (total of 7 items)		17.77	4.80	0.60
General (total of 16 items)		41.72	7.44	0.92
All (total of 30 items)		77.75	12.83	1.59
Positive (mean)		2.61	0.58	0.07
Negative (mean)		2.54	0.69	0.09
General (mean)		2.61	0.47	0.06
All (mean)		2.59	0.43	0.05
Treatment				
Previous hospitalizations		3.23	5.07	0.63
Months in hospital		5.69	8.15	1.01
Current treatment				
Psychotherapy	39 (60.00%)			
Drug therapy	51 (78.50%)			
Antipsychotics	45 (69.20%)			
Defined daily dose				
Antipsychotics		0.682	0.75	0.09
Antidepressants		0.498	0.88	0.11
Mood stabilizers		0.145	0.47	0.06
Central Nervous System stimulants		0.026	0.15	0.02
Anxiolytics (antihistamines)		0.015	0.09	0.01
Anxiolytics (benzodiazepines)		0.074	0.28	0.04
Sedatives (antihistamines)		0.046	0.24	0.03
Sedatives (benzodiazepines)		0.133	0.38	0.05

Note: M = Mean. SD = Standard Deviation. IQ was derived from two subtests of Wechsler Abbreviated Scale of Intelligence (WASI): Vocabulary and Matrix Reasoning or General Ability Index from WAIS-IV (Wechsler, 2008). PANSS = Mean scores on the Positive and Negative Syndrome Scale (Kay et al., 1987) scale from 1 ("absent") to 7 ("extreme"), where a mean score of 4 is considered to be above the psychotic threshold of positive symptoms. Regarding "defined daily dose," medication use is characterised by whether the participant takes the medication (“1”) or not ("0").

2.2 Procedure

This study examines a subset of the GMT project's baseline data on a selected sample of individuals (Haugen et al. 2021; 2022).

A clinical psychologist did the diagnostic evaluation under the instruction of a psychiatrist. For baseline evaluation, individuals completed a broad set of test batteries and clinical questionnaires. The cognitive assessments were conducted by a clinical psychologist or a psychiatric nurse who had received training from a specialist in neuropsychology. The measurement of estimated IQ was done using the General Ability Index from Wechsler Adult Intelligence Scale – IV (WAIS – IV; Wechsler, 2008) or the Vocabulary and Matrix Reasoning subtest from Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

2.3 Measurements

2.3.1 Objective measures of hot EF

Iowa Gambling Task

Iowa Gambling Task (IGT) is a widely used approach for assessing behavioural *decision-making* in clinical and research contexts (Barnhart & Buelow, 2021). We used a computerised version of IGT in this study (Bechara, 2007). The participants are presented with four distinct piles/decks of cards in this assignment. They are instructed to maximise profit, with the fewest possible losses, by selecting cards from the various piles/decks. The ratios and frequencies of gains and losses vary between the decks (see Table 2), and participants are unaware whether the deck is advantageous (Decks C+D) or disadvantageous (Decks A+B). Each participant will complete 100 trials divided into five blocks (20 trials each block). At each trial, the participant selects a card from a deck and is then notified (on the screen) of the amount they won/lost by selecting that card.

Recent research on IGT has shown that a long-term scoring approach is a useful and prevalent scoring method, and it is this scoring method that we have used in our own study (Bechara et al., 1994; Steingroever et al., 2013; Bull et al., 2015). This approach emphasises the long-term outcome to indicate advantageous or prudent *decision-making*. The number of disadvantageous selections is subtracted from the number of advantageous selections ([C+D]-

[A+B]). A positive score indicates more advantageous and appropriate *decision-making*. To quantify and assess *decision-making* skills, the score can be divided into a block net score (20 trials) as well as a total net score (100 trials).

As stated previously, the task can be divided into the ambiguous phase (about trials 1-40) and the risky phase (roughly trials 41-100). Prior research on IGT has either examined each phase individually or taken them into account collectively. In this thesis, we have accounted for them collectively as an IGT net total score.

Previous studies reveal that IGT net scores' test-retest reliability is moderate to strong. The reliability appears to remain over a period of several weeks (*r* =.35–.65; Xu et al., 2013), months (*r* =.43–.47; Cardoso et al., 2010), and years (*r* =.19–.74; Xiao et al., 2013; Tuvblad et al., 2013). However, some studies have shown no correlation on IGT scores over time (De Wilde et al., 2013; Buelow & Barnhart, 2017).

Table 2. *Gain and loss ratios and frequencies in each deck of IGT*

IGT	*Deck A*	*Deck B*	*Deck C*	*Deck D*
Mean gain	+$100	+$100	+$50	+$50
Mean loss	-$250	-$1.250	-$50	-$250
Loss probability (%)	5 every 10 draw (.5)	Once every 10 draw (.1)	5 every 10 draw (.5)	Once every 10 draw (.1)
Expected value	-$250	-$250	+$250	+$250

Note: The currency is USD. Abbreviation: Iowa Gambling Task (IGT). Deck A and B are regarded as disadvantageous or "risky" due to their greater long-term losses, although they may result in greater short-term profits. Deck C and D are regarded as advantageous due to their long-term gains (Bechara et al., 1994: Bechara, 2007).

2.3.2 Objective measures of cool EF

We assessed cool EF using the subtests Tower Test and two conditions from the Color Word Interference Tests from the Delis-Kaplan Executive Function System (D-KEFS; Delis et al., 2001) and the Letter-Number Sequencing subtest from the Wechsler Adult Intelligence Scale Fourth Edition (WAIS-IV; Wechsler, 2008).

Color Word Interference Test

The Color Word Interference Test (CWIT) task has four distinct conditions, each of which may indicate one of the following cognitive functions: *processing speed* (CWIT1 and CWIT2), *inhibition* (CWIT3), and *inhibition/shifting* (CWIT4). We utilised conditions 3 and 4 to assess both cognitive inhibition and flexibility in the current study. The rationale for this approach is that these two conditions measure EF, while the others assess basic cognitive processing.

The third condition (CWIT3) is an inhibition trial that is directly inspired by the Stroop method and the paradigm of showing coloured printed words in a different colour ink (Stroop, 1935; Lippa & Davis, 2010). It has a list of color-coded words printed in a variety of ink colours. The examinee is asked to say the colour of ink used to print the words, and not the spelled word. The participants are required to inhibit the automatic response, which is reading the word.

The fourth condition (CWIT4), which also comprises a list of words printed in various ink colours, differs in that examinees must alternate between reading the written word and naming the discordant ink colour, measuring both inhibitory capacities and mental flexibility. The task is similar to condition 3, but in condition 4 the words are either within or outside of a box. If the word is enclosed in a box, the examinee is required to read it aloud. If the word is not inside a box, the examinee is prompted to name the dissonant ink colour (as in the third condition) (Lippa & Davis, 2010).

We measured the completion time in seconds for both conditions. Taking longer to complete the tasks is interpreted as an indication of difficulties with inhibition or shifting (Delis et al., 2001; Skogli et al., 2016; Kurniadi et al., 2021).

Extensive research has shown the CWIT's performance validity as a measure of executive functioning (Eglit et al., 2019). The internal consistency has been shown to be high on the CWIT, ranging from .62 to .86 (Shunk et al., 2006).

Tower Test

The Tower Test is a *strategic planning* task that assesses mental ability to plan. The participant must construct several target towers by moving five discs of varying sizes around a board with three vertical pegs. The participant is instructed to complete the task using the least possible moves. They are only permitted to move one disc at a time and are not permitted to stack larger discs on top of smaller discs. We utilised the total number of achievements within the time limit provided in the D-KEFS manual. A low raw score indicates poor performance (Delis et al., 2001).

In earlier research, the D-KEFS Tower Test's internal consistency coefficients ranged from $\alpha = .43$ to $\alpha = .84$ (Trakoshis et al., 2022), indicating unacceptable ($\alpha < 0.5$) to good ($0.8 \leq \alpha < 0.9$) internal consistency across studies across age groups (Cronbach, 1951). The test–retest reliability for total achievement score was found to be moderate across all ages ($r = .40$; Delis et al., 2001).

Letter-Number Sequencing

In this study the Letter-Number Sequencing (LNS) subtest from WAIS-IV (Wechsler, 2008) was used to assess verbal working memory/*updating*. The test administrator reads a sequence of letters and numbers to the participant, who is given the task of remembering and recalling the letters in alphabetical order and the numbers in ascending order. This assessment consists of 10 items, each of which contains three trials with an equal number of letters and numbers (Pezzuti & Rosetti, 2017). The participants' performance was assessed based on the number of correctly recalled trials. Low raw scores imply poor performance. The LNS has a test-retest reliability of 0.80, as demonstrated in normative samples (Wechsler, 2008).

Composite score

The raw scores for the cool EF tasks (CWIT3, CWIT4, Tower Test, and LNS) were transformed to z-scores to be combined into a cool EF composite score. CWIT3 and CWIT4 have been reverse-scored to facilitate their merging with the other tasks. Correlations between the cool EF tasks were lower than expected ($r = .12$-$.69$). Several studies, however, endorse the use of composite executive functioning ratings, arguing that the merging scores creates global measures that are more robust against measurement error (Friedman & Miyake, 2017; Hwang et al., 2019). The composite measure used in the present study is in line with a three-component model of executive functioning (inhibition, shifting, and updating) (Friedman & Miyake, 2017). It is also in line with earlier critique of other studies that draw conclusions based on a few tests

(Hwang et al., 2019). Multiple measures, each indicating a distinct aspect of executive functioning, are regarded to describe cool EF as a whole more accurately.

2.3.3 Subjective measures of hot and cool executive functioning

The Behaviour Rating Inventory of Executive Functions for Adults (BRIEF-A; Roth et al., 2005) was used to assess *executive functioning in everyday life* (Isquith et al., 2006). The adult version (18 to 90 years) is a standardised measure with self- and informant-report versions that assess perception of behavioural and emotional manifestations of executive dysfunction in daily life. In this study the self-report version was assessed. Two participants were under the age of 18 (16 and 17 years, respectively) and hence did not complete the BRIEF-A evaluation. These two participants completed the BRIEF-SR (*Behaviour Rating Inventory of Executive Functions Self Report Version*; designed for adolescents) (Guy et al., 2004). Their scores were converted in order to compare them with adults who completed the BRIEF-A.

The BRIEF-A includes 75 items. These 75 items can be grouped into nine clinical scales, which can be subdivided further into two summary index scales and a summary scale thought to indicate overall functioning (Global Executive Composite) (Isquith et al., 2006). The two summary indexes, the Behavioural Regulation Index and the Metacognition Index, are thought to reflect the hot-cool dichotomy of executive functioning, with the Behavoural Regulation Index representing hot executive functioning and the Metacognitive Index representing cool executive functioning (Giancola et al., 2012). In this sense, the BRIEF-A, when divided into two indexes, facilitates the exploration of the sample's hot and cool subjective reported EF.

The Behavioural Regulation Index is composed of the following four clinical scales: Inhibit (abilities relating to impulse control and the ability to inhibit specific behaviours at appropriate times), Shift (the capacity for flexible problem solving and task switching), Emotional Control (the capacity for appropriate emotional regulation), and Self Monitor (the capacity for recognising and monitoring the effect of one's behaviours on others) (Roth et al., 2005; Isquith et al., 2006).

The Metacognition Index is composed of the following five clinical scales: Initiate (the ability to generate ideas and initiate tasks), Working Memory (the ability to continue using information while completing another task), Plan/Organise (the ability to set goals and effectively accomplish them through planning and task execution), Task Monitor (the ability to check and assess one's own performance and work) and Organisation of Material (abilities relating to tidiness and order in workspaces, homes, and materials) (Roth et al. 2005; Isquith et al., 2006).

The BRIEF-A assessment yields *t*-scores based on American norms. Increased *t*-scores indicate more problems. The BRIEF-A has demonstrated good test-retest reliability and validity (Roth et al., 2005; Rabin et al., 2006; Garlinghouse et al., 2010). The various indexes have also demonstrated an acceptable degree of internal consistency, and this study is no exception, with a Cronbach's Alpha score of $\alpha = .74$. The two indexes, Behavioural Regulation Index and the Metacognition Index, also show a high internal consistency, with Cronbach's Alpha scores of $\alpha = .90$ and $\alpha = .92$, respectively.

2.3.4 Objective and subjective measures of social functioning

Social Functioning Scale

The Social Functioning Scale (SFS) is a self-report questionnaire which has been used to assess social functioning in people with psychotic disorders, including schizophrenia (Birchwood et al., 1990). The SFS is one of the most commonly used assessments for social functioning in schizophrenia (Burns & Patrick, 2007). It consists of 79 items designed to reflect the social skills and performances of individuals. All items are additionally classified into 7 domains: social engagement (initiation of conversations, social avoidance, time spent alone), interpersonal behaviour (quality of communication, number of friends), pro-social activities (engagement in a range of common social activities, such as sport), recreation (engagement in a variety of common hobbies, interests, and so on), independence-competence (ability to perform certain skills necessary for independent living), independence-performance (performance of skills necessary for independent living) and occupation (engagement in productive employment). Every subscale score is the sum of all item values of that subscale, and the full scale SFS is the mean of the seven subscales. A sample of 334 individuals with schizophrenia is used to standardise and normalise each subscale result to a Scaled Score (Mean = 100, SD = 15). An increased total score indicates higher social functioning (Birchwood et al., 1990; Iffland et al., 2015). The SFS is regarded as a sensitive, valid, and reliable assessment of social functioning in relation to the impairment and needs of individuals with schizophrenia (Birchwood et al., 1990). The SFS was considered as a subjective measure of social functioning, as it is a self-reported measure.

Global Assessment of Functioning

In this study, we used the Global Assessment of Functioning (GAF) Scale to assess objective social functioning. The GAF is used by mental health professionals to evaluate an individual's psychological, social, and occupational functioning. Although the GAF can be regarded as a measure of global functioning, it is commonly used as an assessment for social functioning in schizophrenia (Burns & Patrick, 2007). As GAF is evaluated by clinicians, it was considered an objective measure of social functioning for the purposes of the present investigation. Typically, the assessment comprises an evaluation of the individual's social, psychological, and occupational functioning abilities. Clinicians evaluate, among other things, the presence or lack of social, occupational, and educational activities, as well as interpersonal relations and personal hygiene. Scores range from 1 to 100, with high scores denoting superior functioning and low scores denoting significant impairment. The procedure for determining a GAF score is to consider all available information about a subject's psychiatric symptoms, as well as his or her social and occupational level, and then to assign a score based on the lowest level of function (Goldman et al. 1992). A 100-point scale is divided into ten intervals, with 91-100 indicating the healthiest and well-functioning individuals and 1-10 indicating the most ill and poorly functioning individuals. The cut-off score for psychosis is considered 40. Although the GAF is frequently used, there has been debate over its validity and dependability (Aas, 2010). However, it has been reported that experienced clinicians make consistent evaluations using GAF (Pedersen et al., 2007). GAF can be either a single score or separate scores for symptoms (GAF-S) and functioning (GAF-F). Only GAF-F was used in the current study.

2.3.5 Measures of symptoms and use of medication

In the analysis, the presence of symptoms and the use of antipsychotic medication were controlled for. Using the Structured Clinical Interview for the Positive and Negative Syndrome Scale for Schizophrenia (SCI-PANSS; Kay et al., 1987), the participants' symptom pressure was measured. Based on clinical interviews with individuals, observations, and additional data from caregivers, SCI-PANSS offers clinical ratings of 30 symptoms, of which 7 are positive symptoms, 7 are negative symptoms, and 16 are general symptoms. Each symptom is scored on a continuum ranging from absent (1) to severe (7). In the current investigation, symptoms were assessed using the SCI-PANSS total score. When administered by qualified clinicians, the inter-rater reliability of the instrument's Norwegian version is adequate (Friis et al., 2003). Regarding medication, it was assessed whether (1) or not (0) the participants were using antipsychotic medication.

2.4 Data analysis

For statistical analysis, IBM Statistical Package for Social Sciences (SPSS) version 27 was used. Prior to analysis, we examined the distribution of scores on all variables for skewness and kurtosis. No corrections were made for skew and kurtosis, as all the scores were normally distributed.

Outliers were defined as scores more than three standard deviations from the mean. Outlying scores were removed from the dataset. As a result, the following sample sizes were used: IGT (n = 64), LNS (n = 61), Tower Test (n = 65), CWIT3 (n = 63), CWIT4 (n = 63), BRIEF Behavioural Regulation Index (n = 58), BRIEF Metacognition Index (n = 58), Social Functioning Scale (n = 55), and Global Assessment of Functioning (n = 65). Some missing data for the BRIEF-A and SFS questionnaires was registered. Due to long assessment days, the participants were allowed to fill out questionnaires at home. The missing data is assumed to be missing at random. There were no statistically significant differences between participants who returned questionnaires and those who did not in terms of demographic, clinical, or cognitive characteristics. This reduces the likelihood of bias.

Pearson correlations were used to examine the relationship between hot EF (IGT, BRIEF-BRI), cool EF (LNS, Tower Test, CWIT3, CWIT4, BRIEF-MI), self-reported social functioning (SFS), and the clinical evaluation of functioning (GAF).

As this study did not include a control group, we used norms from the test manual to describe the sample. For all measures, norms were based on healthy controls except for the SFS, where norms were based on individuals with schizophrenia. For the analysis, however, raw scores were converted to z-scores (with a mean of 0 and a standard deviation of 1). *T*-scores (mean of 50 and standard deviation of 10) were generated for the IGT, BRIEF-BRI, and BRIEF-MI measures. The results of SFS and GAF-F measurements were shown in *z*-scores (with a mean of 0 and a standard deviation of 1). For each hot and cool executive functioning measure, a one-sample *t*-test was used to examine the difference between the sample and the norm group using the mean, standard error, effect size, and level of significance.

Factor analysis for the 4 objective cool EF measures (LNS, Tower Test, CWIT3 and CWIT4) and for the 7 Social Functioning Scale subscales were conducted to test the internal consistency. Kaiser-Meyer-Olkin and Bartlett's tests of sphericity were used to determine whether the data were suitable for factor analysis, and both tests revealed that the data were sufficiently adequate.

After conducting an exploratory factor analysis with principal axis factoring on the seven SFS subscales, it was determined that combining six of the subscales into a single factor resulted in increased internal consistency. The principal axis analysis revealed two factors, with respective eigenvalues of 2.94 and 1.02 (over Kaiser's criterion of 1) and with a combined explained variance of 56.6%. Occupation was the subscale with the lowest internal correlations to the other scales (ranging from .02 to .2). When occupation was excluded Cronbach's Alpha increased from $\alpha = .74$ to $\alpha = .79$. Similar results have been found in a previous study with a similar two-factor structure (Hellvin et al., 2010).

An exploratory factor analysis was performed on the four objective cool EF measures, LNS, Tower Test, CWIT3 and CWIT4, and revealed a single explanatory factor, with an eigenvalue of 1.9 (over Kaiser's criterion of 1) and with a combined explained variance of 47.2%.

Linear regression was used to explore whether objective and subjective measures of cool and hot EF were associated with social functioning measured using Social Functioning Scale (SFS) and Global Assessment of Functioning (GAF). Four distinct linear regressions were conducted in total. Each regression included two models: one with cool EF (objective or subjective) as the sole independent variable and another with both cool and hot EF (objective or subjective) as predictor variables. One regression was conducted to see whether objective measurements of hot and cool EF were predictive of SFS. One regression was conducted to see whether subjective measures of hot and cool EF were predictive of SFS. One regression was conducted to see whether objective measurements of hot and cool EF were predictive of GAF-F. One regression analysis was conducted to see whether subjective measures of hot and cool EF were predictive of GAF-F. We calculated explained variance (r^2), predictive power (F-value), and significance level from the regression analysis (p-value).

The Durbin-Watson test was used to determine the autocorrelation of the residuals in the regression analysis. The numbers were consistent with Durbin & Watson's (1950) statement that values should be as close to 2 as possible, larger than 1, and less than 3.

The *p*-values reported were based on two-tailed tests. Statistically significant effects were defined as those with *p*-values less than 0.05. Cohen's *d* was used to calculate effect sizes, which were then interpreted according to Cohen's (1988) guidelines, specifically small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$).

2.5 Ethical considerations

The study was approved by the Regional Committee for Medical and Health Research Ethics of South-Eastern Norway (2015/2118) and was done in compliance with the Helsinki declaration and Vancouver rules. The hospital's secure research server was used for data storage and only authorised persons had access to the archives securing the confidentiality of participants, as approved by the Regional Committee for Medical Ethics of South-Eastern Norway. The project was also approved by the Privacy Protection Ombudsman for research at the Innlandet Hospital Trust. When participants and clinicians requested it, they received feedback on the various neuropsychological test results. The participants gave their written informed consent to participate in this study, in line with World Medical Association's Declaration of Helsinki on ethical principles for medical research involving human subjects (World Medical Association, 2013). Peer-support workers were involved in the planning and evaluation of the study.

3 Results

3.1 Executive functioning

3.1.1 Descriptive statistics of baseline characteristics

There was an expected association between the two BRIEF-A subscales, Metacognition Index (MI) and Behavioural Regulation Index (BRI), which reflect subjective EF with a significant correlation of $r = .68$, $p = .001$. The objective subtests for cool EF, with the exception of the Color Word Interference Test 3 (CWIT3; *inhibition*) and Color Word Interference Test 4 (CWIT4; *inhibition/shifting*) subtest, did not show a substantial correlation. However, they did correlate with the composite score (total). The composite score (total) and the Letter-Number Sequencing (LNS; *updating*) had a correlation with the measure of hot EF: $r = .30$, $p = .05$; $r = .26$, $p = .05$. However, no significant correlation was found between the objective measure of hot EF and the other objective cool EF values (Tower Task, CWIT3 and CWIT4), see Table 3.

In the subsequent sections the participants' performance on the different tests will be compared to the standardised means derived from large norming samples with healthy participants listed in the test manuals of the instruments (Delis et al., 2001; Roth et al., 2005; Wechsler, 2008). See Figure 2 for a visual representation of the sample's hot and cool EF.

Table 3. *Bivariate correlations between variables*

	Objective cool executive function					Objective hot executive function	Subjective cool executive functioning	Subjective hot executive functioning	Social Functioning Scale	Global Assessment of Functioning
	Total	LNS	Tower Task	CWIT3	CWIT4	IGT	BRIEF MI	BRIEF BRI	Total	Total
Objective cool EF										
Total										
LNS	**,37****									
Tower Task	**,55****	,06								
CWIT3	**,81****	,17	,22							
CWIT4	**,74****	,11	,12	**,68****						
Objective hot EF										
IGT	**,30***	**,26***	,03	,19	,24					
Subjective cool EF										
BRIEF MI	,13	-,15	,21	,10	,16	-,001				
Subjective hot EF										
BRIEF BRI	-,13	-,19	,14	-,15	-,07	-,25	**,68****			
Social Functioning Scale										
Total	**-,40****	,01	**-,36****	**-,30***	**-,33***	-,23	**-,32***	-,10		
Global Assessment of Functioning										
Total	**,25***	,14	,10	,13	,24	-,24	-,09	-,05	,27	

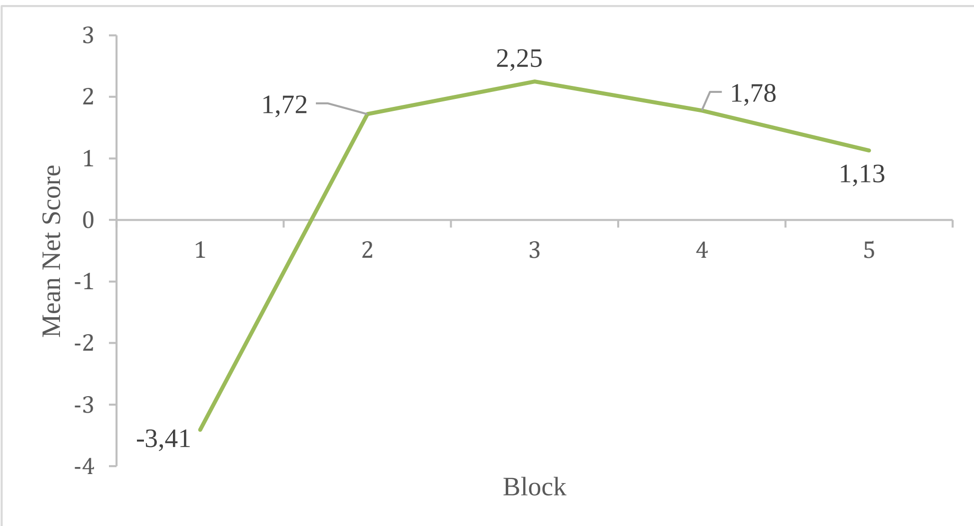
Note: **Bold** indicates significant correlations. ***Indicates that the correlation is significant at the 0.05 level (2-tailed), while **** is significant at the 0.01 level (2-tailed). EF = Executive functions. LNS = Letter-Number Sequencing, Wechsler Adult Intelligence Scale-IV (WAIS-IV; Wechsler, 2008). Tower Task, Delis–Kaplan Executive Function System (D-KEFS; Delis et al., 2001). CWIT = Color-Word Interference Test (D-KEFS; Delis et al., 2001). IGT = Iowa Gambling Task (Bechara, 2007). MI = Metacognition Index, Behavior Rating Inventory of Executive Function (BRIEF; Roth et al., 2005). BRI = Behavioral Regulation Index (BRIEF; Roth et al., 2005).

3.1.2 Descriptive statistics of hot EF

3.1.2.1 Objective measures of hot EF

On the Iowa Gambling Task (*decision-making*), the participants performed worse (M = 45.7, SE = 10.88) compared to the normative mean (M = 50, SE = 10). This difference, -4.3, BCa 95% CI [-7.01, -1.58], was statistically significant $t(63) = -3.16$, $p = .002$. This difference represented a small-sized effect based on the guidelines for interpretation of Cohen's d (Cohen, 1988), d = -.38.

Figure 1. *Iowa Gambling Task performance across blocks throughout the assessment*



Note: Figure 1 provides mean net scores for each block on the Iowa Gambling Task (Bechara, 2007). The figure illustrates the participants' performance across time. Mean Net Score is assessed with (C+D)-(A+B). A positive graph slope illustrates that the average of participants chooses more advantageous cards over disadvantageous cards.

Figure 1 shows that participant performance improved from block 1 to block 3, with mean net scores increasing from -3.41 to 2.25. However, the participant's improvement is temporary, as mean net scores drop from block 3 to 5, with respective scores decreasing from 2.25 to 1.13.

3.1.2.2 Subjective measures of hot EF

On average, the participants reported higher scores (more impaired) on the BRIEF-A subscale Behavioral Regulation Index (BRI) (M = 58.93, SE = 10.79), compared to the norm group (M = 50, SE = 10). This difference, 8.39, BCa 95% *CI* [6.09, 11.77] was statistically significant $t(57) = 6.31$, p<001. This difference represented a large-sized effect, d = .83 (Cohen, 1988).

3.1.3 Descriptive characteristics of cool EF

3.1.3.1 Objective measures of cool EF

For a detailed representation of the results, see Table 4. The participants performed, on average, adequately on the Letter-Number Sequencing (*updating*) (n=61) compared to the norm group. The difference between participants and the norm group was not significant. This difference represented a small-sized effect. On the Tower test (*planning*) (n=65), the participants performed similar to the norm group. This difference was not significant. The difference represented a small-sized effect.

On Color Word Interference (n=63) the participants performed worse on the CWIT3 (*inhibition*) and the CWIT4 (*inhibition and shifting*) tests, compared to the normative mean. These differences were significant and both differences represented a medium-sized effect (see Table 4).

Table 4. *Scores on measures of objective cool executive functioning*

			Study sample		**Norms**		**95 % Confidence Interval**			
	t	df	*M*	*SE*	*M*	*SE*	Lower	Upper	Sig.	Effect size
LNS *SS*	-.88	60	9.69	2.75	10	3	-.10	.39	.19	-.11
Tower Test *SS*	1.52	64	10.49	2.60	10	3	-.15	1.14	.07	.19
CWIT3 *SS*	-5.3	62	7.76	3.35	10	3	-3.08	-1.39	**<.001**	-.67
CWIT4 *SS*	-5.08	62	7.6	3.74	10	3	-3.34	-1.45	**<.001**	-.64

Note: M = Mean (Normalised *t*-score). SE= Standard Error. **Bold** values are significant at the $p < .05$ level in a two-tailed test. Effect size based on Cohen's *d*. *Letter-Number Sequencing* Scaled Score (LNS SS) (Wechsler, 2008). Tower Test Scaled Score (Tower Test SS). *Color Word Interference Test 3 Scaled Score* (CWIT3 SS), *Color Word Interference Test 4 Scaled Score* (CWIT4 SS) (D-KEFS; Delis et al., 2001).

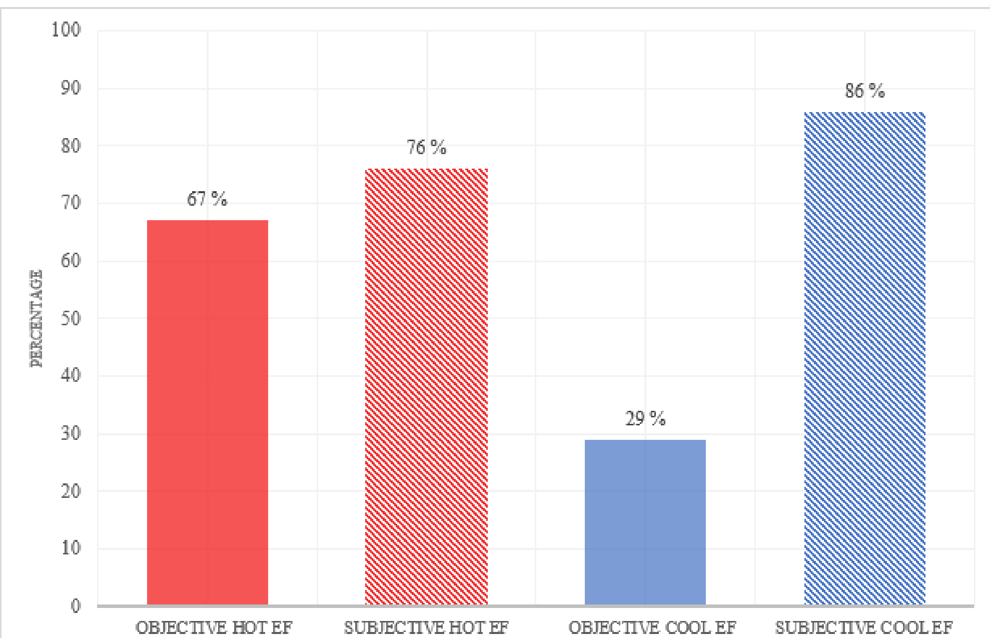
3.1.3.2 Subjective measures of cool EF

On average, the participants reported higher (more impaired) scores on the BRIEF-A subscale Metacognition Index (MI) (M = 64.76, SE = 11.31), compared to the norm (M = 50, SE = 10). This difference, 14.76, BCa 95% CI [11.78, 17.73] was significant $t(57) = 9.93$, $p<.001$. This difference represented a large-sized effect, d = 1.3.

3.1.4 Outcomes of hot and cool EF: summary and comparison

The findings indicate clearly that the individuals perform worse on executive tasks in general compared to norms. In comparison to the normative mean, a greater proportion of participants achieve lower scores for objective hot EF than for objective cool EF. In terms of subjective EF, a greater proportion of participants score lower on cool EF than on hot EF. Figure 2 provides an illustration of hot and cool EF in the sample.

Figure 2. *Percentage of participants scoring lower than the normative mean*



Note: Objective hot EF includes Iowa Gambling Task (Bechara, 2007). Subjective hot EF includes BRIEF-A subscale Behavioral Regulation Index (Roth et al., 2005). Objective cool EF includes Letter-Number Sequencing (Wechsler, 2008), Tower Test and Color Word Interference Test 3 and 4 (Delis et al., 2001). Subjective cool EF includes BRIEF-A subscale Metacognition Index (Roth et al., 2005).

3.2 Descriptive statistics of social functioning

On average, the participants had low scores on the Global Assessment of Functioning (M = 42.78, SE = 8.76), indicating serious impairment in social or occupational functioning.

On average, the participants reported similar scores on the Social Functioning Scale (M = 101.59, SE = 8.68), compared to the norm based on individuals with schizophrenia (M = 100, SE = 15). The range of scores was large with a minimum score of 82.17 and a maximum score of 120.17. A high score indicates good social functioning.

3.3 Associations between objective and subjective hot and cool executive functioning and measures of social functioning

Linear regression was used to test whether objective and subjective measures of cool and hot EF were associated with social functioning measured with Social Functioning Scale (SFS) and Global Assessment of Functioning (GAF) (see Table 5).

The strongest predictor of scores on the SFS was objective cool EF with a larger beta-coefficient and greater explained variance. Similar findings were found for subjective measures of cool EF, where Metacognition Index (subjective cool EF) explained more of the variance in scores on the SFS than Behavioral Regulation Index (subjective hot EF).

GAF scores were better explained by hot and cool measures of objective EF together, than by cool EF alone, Δr^2 = .08 to .21. However, this finding does not apply to subjective measures. The subjective measures of EF had no predictive value concerning GAF. See Table 5 for a complete overview of the regression analysis. For a visual representation of the regression analysis, see Figure 3.

Table 5. *Linear model of predictors of scores on Social Functioning Scale and Global Assessment of Functioning*

Linear Models		B (95% CI)	SE B	*β*	Sig.	r^2
SFS						
Model 1						.20
	Constant	.026	.081			
	Cool EF	-.428 (-.67, -.187)	.120	-.446	**<.001**	
Model 2						.23
	Constant	.042	.081			
	Cool EF	-.375(-.625, -.126)	.124	-.391	**.004**	
	Hot EF	-.004 (-.009, .001)	.003	-.190	.149	
Model 3						.30
	Constant	1.054	.484			
	Cool EF	-.384 (-.625, -.142)	.120	-.400	**.002**	
	Hot EF	-.004 (-.009, .002)	.003	-.170	.182	
	SCI-PANSS	-.013 (-.026, -.001)	.006	-.255	**.039**	
Model 4						.38
	Constant	.917	.464			
	Cool EF	-.319 (-.555, -.083)	.117	-.332	**.009**	
	Hot EF	-.004 (-.009, .001)	.002	-.203	.097	
	SCI-PANSS	-.015 (-.027, -.003)	.006	-.290	**.015**	
	Antipsychotics	.412 (.079; .744)	.165	.294	**.016**	
SFS						
Model 1						.10
	Constant	1.20	.512			
	MI	-.016 (-.028, -.002)	.007	-.319	**.021**	
Model 2						.14
	Constant	1.02	.535			
	MI	-.022 (-.04, -.006)	.009	-.460	**.010**	
	BRI	.013 (-.01, .042)	.012	.208	.169	
Model 3						.29
	Constant	3.170				
	MI	-.028 (-.045, -.012)	.008	-.578	**.001**	
	BRI	.014 (-.007, .036)	.011	.223	.184	
	SCI-PANSS	-.023 (-.036, -.009)	.007	-.421	**.002**	
Model 4						.32
	Constant	2.885	.820			
	MI	-.024 (-.041, -.007)	.009	-.494	**.007**	
	BRI	.011 (-.010, .033)	.011	.174	.302	
	SCI-PANSS	-.023 (-.037, -010)	.007	-.434	**.001**	
	Antipsychotics	.282 (-.100, .665)	.190	.190	.145	
GAF_F						
Model 1						.08
	Constant	42.86	1.077			
	Cool EF	3.63 (.43, 6.83)	1.600	.281	**.027**	
Model 2						.21
	Constant	43.255	1.014			
	Cool EF	5.09 (1.96, 8.22)	1.565	.394	**.002**	
	Hot EF	-.105 (-.172, -.038)	.0340	-.379	**.003**	

Model 3						.33
	Constant	61.241	5.808			
	Cool EF	4.914 (1.990, 7.898)	1.461	.380	**.001**	
	Hot EF	-.100 (-.163, -.037)	.031	-.361	**.002**	
	SCI-PANSS	-.232 (-.379, -.084)	.074	-.339	**.003**	
Model 4						.36
	Constant	60.072	5.725			
	Cool EF	5.521 (2.581, 8.460)	1.468	.427	**.000**	
	Hot EF	-.106 (-.168, -.044)	.031	-.383	**.001**	
	SCI-PANSS	-.250 (-.396, -.104)	.073	-.366	**.001**	
	Antipsychotics	3.826 (-.311, 7.962)	2.066	.203	.069	
GAF_F						
Model 1						.01
	Constant	47.598	6.816			
	MI	-.057 (-.231, .116)	.087	-.088	.512	
Model 2						.01
	Constant	47.378	7.210			
	MI	-.065 (-.303, .172)	.119	-.100	.584	
	BRI	.016 (-.298, . 33)	.156	.019	.919	
Model 3						.38
	Constant	73.187	11.170			
	MI	-.134 (-.363, .094)	.114	-.207	.243	
	BRI	.027 (-.267, .322)	.147	.032	.853	
	SCI-PANSS	-.271 (-.458, -.084)	.093	-.379	**.005**	
Model 4						.38
	Constant	71.187	11.561			
	MI	-.111 (-.354, .131)	.121	-.171	.362	
	BRI	.009 (-.293, .312)	.151	.011	.951	
	SCI-PANSS	-.275 (-.464, -.087)	.094	-.385	**.005**	
	Antipsychotics	1.633 (-3.820, 7.086)	2.719	.081	.551	

Note: **Bold** p-values indicate significant predictors. Regarding SFS (Birchwood et al., 1990), model 1 was considered the better fit as there was no significant F-change for model 2. When it comes to GAF (Goldman et al. 1992) and objective measures, model 2 was considered a better fit. Cool EF refers to objective cool EF. Hot EF refers to objective hot EF. MI refers to subjective cool EF. BRI refers to subjective hot EF. GAF refers to objective social functioning. SFS refers to subjective social functioning. Abbreviation: MI = Metacognition Index (BRIEF-A; Roth et al., 2005), BRI = Behavioral Regulation Index (BRIEF-A; Roth et al., 2005), SCI-PANSS = Structured Clinical Interview for the Positive and Negative Syndrome Scale for Schizophrenia (Kay et al., 1987).

3.3.1 Associations between executive functioning and results on the Social Functioning Scale

3.3.1.1 Associations between objective measures of hot and cool EF and SFS

The negative association between objective cool EF and the SFS was statistically significant. Elevated (good) scores on objective cool EF were associated with lower scores on the SFS, indicating low social functioning.

Objective measures of hot EF were not significantly associated with the SFS score. When controlling for objective hot EF, the association between objective cool EF and the SFS remained significant, and the direction of the association remained negative. The Model 2 regression did not increase the explained variance significantly.

Psychotic symptoms were significantly and negatively associated with the SFS. When controlling for symptoms of psychosis, the association between objective cool EF and the SFS remained significant, and the direction of the association remained negative. The Model 3 regression explained significantly more of the variance than the Model 2 regression.

Antipsychotic medication was significantly and positively associated with the SFS. When controlling for antipsychotic medication, the association between objective cool EF and the SFS remained significant, and the direction of the association remained negative. The model 4 was considered the best statistical fit with a significant F-change when adding both SCI-PANSS and antipsychotic medication to the regression (Δr^2 = .08). The cool EF predictor remained significant after controlling for SCI-PANSS and antipsychotic medication. The SFS scores were better explained by hot and cool measures of objective EF, SCI-PANSS and antipsychotic medication together, Δr = .38, than by cool EF alone, Δr = .20.

3.3.1.2 Associations between subjective measures of hot and cool EF and SFS

Subjective measures of cool EF explained more of the variance in scores on the SFS than subjective measures of hot EF. The negative association between subjective cool EF and the SFS was statistically significant.

Subjective measures of hot EF were not significantly associated with the SFS. When controlling for subjective hot EF, the association between subjective cool EF and the SFS remained significant, and the direction of the association remained negative. The Model 2 regression did not increase the explained variance significantly.

Psychotic symptoms were significantly and negatively associated with the SFS. When controlling for symptoms of psychosis, the association between subjective cool EF and the SFS remained significant, and the direction of the association remained negative. The Model 3 regression explained significantly more of the variance than the Model 2 regression.

Antipsychotic medication was not significantly associated with the SFS. When controlling for antipsychotic medication, the association between subjective cool EF and the SFS remained significant, and the direction of the association remained negative. The Model 4 regression did not explain significantly more of the variance than the Model 3 regression.

The model 3 was considered the best statistical fit with a significant F-change when adding SCI-PANSS to the regression (Δr^2 = .17). However, the cool EF predictor remained significant after controlling for SCI-PANSS. The SFS scores were better explained by hot and cool measures of subjective EF and SCI-PANSS together, Δr = .29, than by cool EF alone, Δr = .10.

3.3.2 Associations between executive functioning and Global Assessment of Functioning

3.3.2.1 Associations between objective measures of hot and cool EF and GAF

It was found that the objective measures of cool EF were significantly and positively associated with the outcome on the GAF. The positive association between objective cool EF and the GAF was statistically significant.

Objective measures of hot EF were also significantly associated with the outcome on the GAF, however in a negative direction. The Model 2 regression explained significantly more of the variance than the Model 1 regression.

Psychotic symptoms were significantly and negatively associated with the GAF. When controlling for symptoms of psychosis, the association between objective cool EF and the SFS remained significant. The Model 3 regression explained significantly more of the variance than the Model 2 regression.

Antipsychotic medication was not associated with the GAF. When controlling for antipsychotic medication, the association between objective cool EF and the GAF remained significant and the direction of the association remained positive. The Model 4 regression did not explain significantly more of the variance than the Model 3 regression.

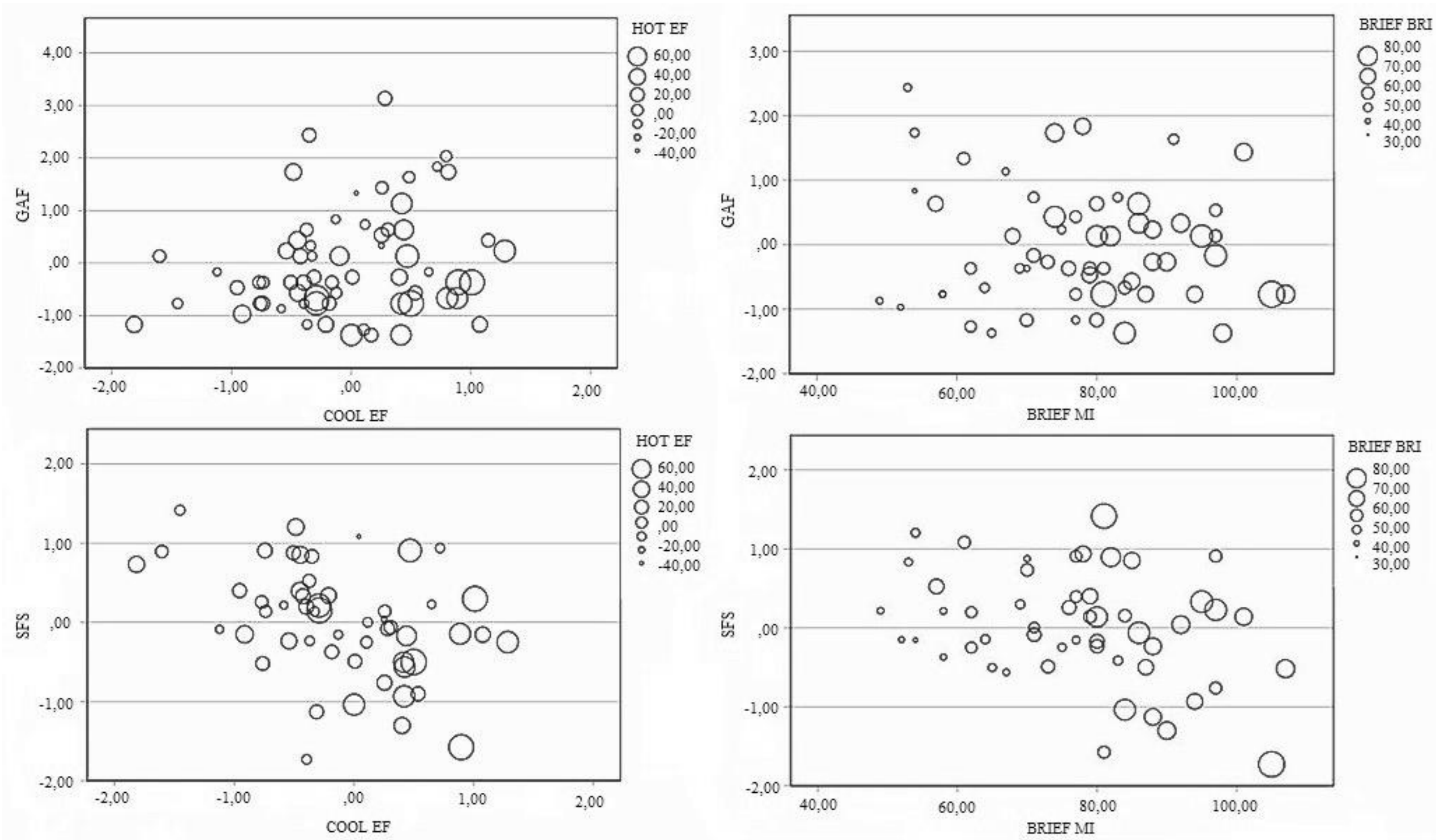
The model 3 was considered the best statistical fit with a significant F-change when adding SCI-PANSS to the regression (Δr^2 = .12). However, the cool EF predictor remained significant after controlling for SCI-PANSS. The GAF scores were better explained by hot and cool measures of objective EF and SCI-PANSS together, Δr = .33, than by cool EF alone, Δr = .08.

3.3.2.2 Association between subjective measures of hot and cool EF and GAF

It was found that the subjective measures of cool EF were not significantly associated with the outcome on the GAF. Furthermore, subjective measures of hot EF were not significantly associated with the outcome on the GAF.

When controlling for psychotic symptoms, a significant negative association was found between the SCI-PANSS score and the GAF. Antipsychotic medication was not significantly associated with GAF. Model 3 was considered the best statistical fit with a significant F-change when adding SCI-PANSS to the regression ($\Delta r^2 = .37$). The GAF scores were better explained by hot and cool measures of subjective EF and SCI-PANSS together, $\Delta r = .38$, than by cool EF alone, $\Delta r = .01$.

Figure 3. *Graphical representation of the regression analysis*



Note: The function along the Y-axis represents the Social Functioning Scale (SFS; Birchwood et al., 1990) and Global Assessment of Functioning (GAF; Goldman et al., 1992), respectively. The predictors along the X-axis are measures of cool executive functions, both objective (labelled COOL EF) and subjective (labelled BRIEF MI). The size of the bubbles represents the score of hot executive functions, both objective (labelled HOT EF) and subjective (labelled BRIEF BRI).

4 Discussion

4.1 Impaired hot and cool EF in individuals with schizophrenia spectrum disorders

In accordance with our hypothesis, our results demonstrate deficits in both hot and cool EF in individuals with schizophrenia relative to norms. Our findings extend the existing knowledge about EF in schizophrenia through the implementation of multiple objective and subjective measures of hot and cool EF in the same study. In light of the paucity of hot EF measures relative to cool EF measures in prior research in schizophrenia, our study provides valuable evidence regarding hot EF deficits in non-chronic individuals with schizophrenia, to the best of our knowledge.

General deficits in cool EF are a robust finding in schizophrenia research (East-Richard et al., 2020; Abramovitch et al., 2021). Our study contributes to the evidence of a general executive dysfunction in schizophrenia, with the use of multiple cool EF measures. This study is unique in that both objective and subjective assessments of hot and cool EF were used.

Regarding the performance of the individuals with schizophrenia on objective cool EF, this investigation yielded conflicting results. First, in line with prior research, the performance of the individuals with schizophrenia was impaired compared to norms on the *Color-Word Interference Test 3* (CWIT3) and the *Color-Word Interference Test 4* (CWIT4), measuring *inhibition* and cognitive flexibility (*shifting*) (Savla et al., 2011; Snyder et al., 2015; Laere et al., 2018). Contrary to past findings, the performance of the individuals with schizophrenia was not impaired compared to norms on *planning* (Tower Test) and verbal working memory/*updating* (Letter-Number Sequencing). Research has shown deficits in these cognitive domains among individuals with schizophrenia (Savla et al., 2011; Botero et al., 2013; Michel et al., 2013; Lee et al., 2015). However, these studies used samples with older individuals. Lee and colleagues (2015) study pointed out antipsychotic medication as one of the possible explanations, making it possible that chronic courses of the illness with long-time use of antipsychotic medication may explain poor performance on the Letter-Number Sequencing in this case. The absence of deficits on the Tower Test and the Letter-Number Sequencing in our sample, may be explained by the absence of chronic individuals with schizophrenia in our sample, with our participants not being in treatment or receiving antipsychotic medication for more than five years.

Consistent with prior findings, our study demonstrated a deficit in objective hot EF in individuals with schizophrenia relative to norms (Lee et al., 2009) The Iowa Gambling Task (IGT), the objective hot EF measure used in this study, has been used in schizophrenia research before, with mixed results (Sevy et al., 2007). Sevy and colleagues (2007) found, consistent with our finding, impairments in IGT-performance in individuals with schizophrenia. However, they argue that small sample sizes in many studies may account for some mixed results regarding IGT-impairment in individuals with schizophrenia. Their study included 27 individuals with schizophrenia, and suggested the use of a larger sample to confirm their findings. Thus, our study with a larger sample, may confirm their results.

Furthermore, a comprehensive meta-analysis on IGT in schizophrenia using 29 samples and more than a thousand individuals with schizophrenia was consistent with our findings (Betz et al., 2018). Our findings regarding the performance on IGT across blocks throughout the assessment, see Figure 1, are coherent with a curve relatively similar to that of past research, which may indicate a difficulty to learn and adhere to contingencies relative to healthy controls (Stratta et al., 2015; Brown et al., 2015; Betz et al., 2018). In contrast to healthy controls, whose IGT performance indicates a steep learning curve, the IGT performance of individuals with schizophrenia tends to stagnate, particularly during the risky phase of the assessment. This means that individuals with schizophrenia tend to perform worse on the IGT in the latter phase, possibly due to difficulties in reinforcement learning or in sustained attention (Brown et al., 2015). Healthy controls typically increase their performance in the latter phase. This may possibly explain why they perform worse compared to norms. Our study replicates previous findings from studies with mainly chronic individuals with schizophrenia for longer, to a large sample of young participants recently diagnosed with the disorder (Ritter et al., 2004; Brambilla et al., 2012; Kim et al., 2012; Hori et al., 2014; Betz et al., 2018).

Self-reported difficulties on the BRIEF-A in schizophrenia have been demonstrated in earlier research (Kumbhani et al., 2010; Power et al., 2012; Bulzacka et al., 2013). Compared to norms, our group of individuals with schizophrenia also reported difficulties on both BRIEF-A indexes: Behavioral Regulatory Index and Metacognitive Index. These subscales have been proposed to reflect the hot-cool dichotomy of EF (Egeland & Fallmyr, 2010). Two of the aforementioned studies used a small sample with older individuals (Kumbhani et al., 2010; Bulzacka et al., 2013). Power and colleagues (2012) used a much larger sample consisting of chronic and institutionalised individuals. Our results indicating significant elevated self-reported EF difficulties supports previous research results by using a larger sample consisting of non-chronic individuals who received treatment for less than five years. In this sense, our findings may imply that EF impairment can be regarded as a core characteristic in schizophrenia and not a result of institutionalisation and chronicity.

4.2 The association between executive functioning and social functioning

A significant positive association was found between objective cool EF and objective, clinician-based, social functioning. Good performance on tasks measuring *inhibition*, *updating*, *shifting*, and *planning* was associated with good, clinician-based, social functioning. This finding is consistent with our expectations and strengthens previous findings about the importance of cool EF for social functioning in individuals with schizophrenia. Prior research has indicated that objective cool EF is important for functional outcomes such as social engagements, social relationships, self-management, maintaining employment, communication ability, empathy and interpersonal problem-solving skills in individuals with schizophrenia (Docherty, 2005; Zanello et al., 2006; Lasser et al., 2007; Shamay-Tsoory et al., 2007; Langdon et al., 2014; Lepage et al., 2014; Dodell-Feder et al., 2015; Najas-Garcia et al., 2018; Madjar et al., 2019). In the present thesis, we hypothesised that the inclusion of measures of hot EF would enhance the explanatory power of EF on both subjective and objective measures of social functioning. Only the association between objective cool and hot EF and objective social functioning was found to be confirmed by this hypothesis. Moreover, when psychotic symptoms were taken into account, the explanatory power of EF on objective social functioning increased. Intuitively, our findings indicate that an increase in symptom pressure is associated with a decline in objective, clinician-based social functioning.

There was a significant negative association between objective hot EF and objective social functioning. Surprisingly, good performance in *decision-making* (IGT) is associated with lower scores on objective social functioning. Global Assessment of Functioning (GAF) is acknowledged as a relatively broad measure, with limitations regarding its interpretability, of functioning, encompassing psychological, social, and occupational functioning (Goldman et al. 1992; Burns & Patrick, 2007). Although the GAF is commonly used as a measure of social functioning (Burns & Patrick, 2007), it is difficult to separate social functioning from other aspects of functioning. To our knowledge, this specific association has not been previously investigated, making comparisons with earlier findings difficult. Our findings suggest that clinicians tend to evaluate individuals who make consistent and advantageous decisions as less socially functional than those who may be more impulsive and risk-seeking. It could be that personality traits such as risk-seeking and impulsivity facilitate social relationships in the population with schizophrenia because they may tend to seek social relations to a greater extent. The unexpected negative association between objective hot EF and objective social functioning may also be attributed to an overestimation of social functioning in individuals with schizophrenia with cognitive impairments, and in this sense, a possible underestimation of social functioning in those who have adequate objective hot EF (Harvey & Pinkham, 2015). However, we cannot rule out the possibility of a third variable influencing the association between EF and social functioning. Our study is a cross-sectional study; hence we cannot determine the causality of the association between EF and social functioning.

Firstly, the lack of an association between objective hot EF and subjective social functioning may be due to the fact that the composite score from the Social Functioning Scale (SFS) we utilised in our study, does not sufficiently reflect the functional areas that have been shown to be associated with hot EF in prior research. A prior study has found a positive correlation between performance on IGT, notably in the risky phase, and community functioning among individuals with schizophrenia (Stratta et al., 2015). Stratta and colleagues (2015) assessed community functioning using the Specific Level of Function Scale (SLOF; Schneider & Struening, 1983), an interview-based objective measure of physical functioning, community activities, interpersonal skills, social acceptability, occupational skills, and personal care. Significant correlations were found between *decision-making* performance during the risky phase and functional areas such as occupational skills, community activities, and interpersonal skills. Previous research has shown that the functional measurements SLOF and SFS are quite similar, with a correlation coefficient of 0.56 (Sumiyoshi et al., 2016). Considering this, one would expect that hot EF would be associated with SFS subscales. A plausible cause for the lack of an association between hot EF and social functioning in our study may be the exclusion of the occupation subscale from the composite score of subjective social functioning. As mentioned previously, occupation was excluded due to its low internal correlations with the other SFS scales. When excluded, the internal consistency of the SFS measure increased. Due to the exclusion of the occupational subscale, our assessment of subjective social functioning may not have captured the specific social and occupational abilities previously associated with *decision-making* performance in IGT.

Secondly, the lack of an association between objective hot EF and subjective social functioning may be due to IGT's demanding, complex nature (Bagneux et al., 2013). The deficits exhibited by individuals with schizophrenia throughout the IGT assessment, particularly during the risky phase, have been linked to difficulties with reinforcement learning (Brown et al., 2015). Further, deficits in reinforcement learning have been shown to be conditioned by working memory/*updating* in individuals with schizophrenia (Collins et al., 2017). IGT tends to require a well-functioning *updating* so that participants can distinguish between experimental conditions and contingencies during the entire assessment (Bagneux et al., 2013). However, our findings indicate that *decision-making* is impaired compared to norm, even though *updating* (Letter-Number Sequencing) capacity is adequate. This disparity may be attributed to our sample's young age, as more chronically ill individuals with schizophrenia may have reduced *decision-making* and working memory/*updating* abilities (Brambilla et al., 2012; Hori et al., 2014; Lee et al., 2015). In this sense, a possible explanation for the lack of an association between objective hot EF and subjective social functioning may be due to adequate mean scores on *updating* (Letter-Number Sequencing). Due to the sample's heterogeneity in hot EF and working memory/*updating*, the link may not be as evident. An association may emerge in a larger sample consisting of a greater number of individuals with schizophrenia and more severe impairments in both *decision-making* and *updating*. This may increase the statistical power to make possible association apparent.

A possible explanation for the negative association between objective cool EF and subjective social functioning may be that individuals with better objective cool EF are able to reflect over and be more critical of their own social functioning. It has been demonstrated that self-criticism is positively associated with impaired social functioning and stress reactivity in individuals with schizophrenia spectrum disorders (Martins et al., 2019). This may indicate that the individuals with better objective cool EF do have good social functioning but are affected by their own self-criticism and therefore rate their own social functioning as worse than it actually is. Unfortunately, we did not control for self-criticism in our study.

The range of the SFS scores in our sample was large, with a minimum score of 82.17 (poorer social functioning) and a maximum score of 120.17 (better social functioning), indicating that some participants report better social functioning. However, this does not necessarily imply that they have good social functioning. In fact, the normative mean of the SFS, the subjective measure of social functioning in our study, is based on individuals with schizophrenia (Birchwood et al., 1990). Studies assessing the SFS on healthy controls show a mean SFS score of 127.5 (SD = 3.7), indicating that although some individuals in our sample report better social functioning than other individuals with schizophrenia, they may still perform worse than healthy controls on group level (Øie et al., 2011).

Dickerson and colleagues (1997) argue that individuals with schizophrenia and their caregivers evaluate the social functioning of the individual similarly. In their study, they used the SFS, and their sample consisted of individuals with schizophrenia with intact cognitive functioning (Dickerson et al., 1997). Thus, it is possible that individuals with intact cognitive functions have a better ability to evaluate their reduced social functioning more realistically. Multiple factors may partly explain why individuals with better cognitive functioning are reporting more difficulties in social functioning. Harvey and Pinkham (2015) identified characteristics in individuals with schizophrenia potentially affecting the accuracy of self-reports. Impaired cognition in individuals with schizophrenia was likely to cause an overestimation of functional capabilities in self-assessment. In this sense, it is possible that better cognitive functioning enables the individuals to adapt a more realistic view of their own social functioning. This greater understanding of their own limitations in social functioning may be missing in individuals with poorer objective cool EF.

Other clinical factors such as low depressive symptoms and the presence of psychotic or negative symptoms could also cause this overestimation on self-assessments, through a general unawareness of the consequences of the illness among individuals with schizophrenia (Harvey & Pinkham, 2015). When including antipsychotic medication in the model, the explanatory power increases further, indicating that the use of antipsychotic medication also explains some of the variance in subjective social functioning. This may suggest that the use of antipsychotic medication can partially explain why certain individuals have better subjective social functioning. A significant positive association was observed between the use of antipsychotic medication and better self-reported social functioning, which may be explained by the alleviation of symptoms. Inclusion of symptoms in the regression increased the explanatory power of subjective social functioning, suggesting that the presence or absence of significant symptom pressure may serve as a predictor of subjective social functioning. A significant negative association was discovered between symptoms and subjective social functioning, however the association was weak. This contradicts earlier findings of a strong association between social functioning and symptoms in schizophrenia. However, these findings are based on objective measures of social functioning, in older and more chronically ill individuals with schizophrenia than those in our sample (Brissos et al., 2011). The prevalence of symptoms over a longer period may be more detrimental to social functioning, possibly through institutionalisation and the absence of occupational and social activities caused by positive and negative symptoms. Controlling for the use of antipsychotic medication and the presence of symptoms did not alter the significant negative association between objective cool EF and subjective social functioning, suggesting that the impact of clinical factors on social functioning is relatively limited, as demonstrated by earlier studies, in comparison to objective cool EF (Norman et al., 1999; Tandon et al., 2020).

Schizophrenia is characterised by insight-related problems, however there is individual variation (Joseph et al., 2015). In fact, overestimation and underestimation of cognitive abilities, symptoms and function are common in schizophrenia (Harvey & Pinkham, 2015; Harvey et al., 2019). Research has shown that better insight is associated with less EF impairment (Burton et al., 2011). This may suggest that the individuals with better objective cool EF in our study may have rated their own social functioning to be lower than those with impaired objective cool EF due to having greater insight. Unfortunately, our study did not have measures of insight. Burton and colleagues (2016) found that 78.5% of the individuals with schizophrenia had neurocognitive impairment. Out of these individuals, 54% had impaired neurocognitive insight, meaning that they reported few neurocognitive deficits when they in fact had neurocognitive deficits on objective tests. In this sense, the individuals in our sample with impaired objective cool EF, may also have impaired neurocognitive insight, and as such, overestimate their own social functioning.

Coping mechanisms related to poor insight, such as positive reappraisal, may influence how individuals with schizophrenia comprehend the consequences of their illness. Positive reappraisal coping mechanisms may lead to the avoidance of negative occurrences, resulting in inflated self-assessments of social functioning (Lysaker et al., 2003). This can be interpreted as an explanation of the overestimation of functional capabilities found in previously mentioned studies (Harvey & Pinkham, 2015). Extending the argument of the avoidance of negative occurrences, individuals with less EF impairment may be more concerned with avoiding excessive stress to prevent illness progression or psychotic episodes. Furthermore, they may be more at ease in their own company and less concerned with the social aspect. They may be more in charge and frugal towards how they use their energy. For instance, the avoidance of vocational activities may be a consequence of positive reappraisal, through the avoidance of negative occurrences. Harvey & Pinkham (2015) have shown that the absence of work-experience may lead to an overestimation of functional and vocational capabilities, and it is thought that the absence of context and own experience can lead to this overestimation in self-assessment.

The negative correlation between objective cool EF and subjective social functioning may be attributable to and dependent on whoever they compare themselves to. In fact, it is possible that the individuals with less impaired cool EF are more social because cool EF is essential for social interaction, and better cool EF may be beneficial for being social (Madjar et al., 2019). In this sense, the individuals with less impaired cool EF may have a greater opportunity to compare themselves to other healthy, well-functioning individuals, given that they are in social relationships. By comparing themselves to healthy individuals, their self-reported social difficulties may become more apparent. In addition, individuals with better objective cool EF may report poor social functioning, as they functioned better socially before being ill. They may have suffered a decline in social functioning due to the onset of schizophrenia, and as a result, they report having more social difficulties compared to before illness onset. On the other hand, it is possible that individuals with impaired objective cool EF never functioned well socially, and therefore may be unaware of a major drop in social functioning. Cumulatively, this may indicate that the basis of comparison is important in self-reported social functioning.

The validity of the subjective measure of social functioning is also a topic of some controversy. The SFS has been regarded as a reliable instrument with high construct validity and internal consistency. In schizophrenia research, it has frequently been noted that factors such as poor insight, demand characteristics, and social desirability bias affect the validity of self-report assessments (Bell et al., 2007; McCambridge et al., 2012; DeVylder & Hilimire, 2015). In this sense, our findings indicating an association between elevated objective cool EF and low subjective social functioning may in part be explained by other factors.

As previously mentioned, our results indicated that objectively measured social functioning, measured with the GAF, was positively associated with measures of objective cool EF. As the GAF is conducted by a clinician, it is not vulnerable to insight-related limitations. Furthermore, research has advocated for the validity of assessments of cognition and functioning in schizophrenia done by clinicians (Harvey & Pinkham, 2015). In fact, when the measure of social functioning is objective, and not a self-report, the association is positive, suggesting that the other factors affecting the validity of self-reported measurements in schizophrenia may play an important role. However, the GAF has been criticised for being too general with one score, which combines social, psychological, and occupational functioning, thus making the discord hard to interpret (Burns & Patrick, 2007). In addition, the knowledge the clinicians have about the individuals with schizophrenia may also be limited.

To sum up, our findings indicate that both hot and cool EF are impaired in individuals with schizophrenia spectrum disorders. Our study extends the current knowledge on hot EF and contributes to the current evidence indicating hot EF deficits in individuals with schizophrenia. In addition, our results indicate that better objective and subjective cool EF were associated with more impairment in subjective social functioning. Hot EF alone did not predict social functioning. Our findings suggest that hot EF is not as crucial for social functioning as limited research has suggested.

4.3 Implications

This current investigation has potential clinical implications. Deficits in EF have been associated with less engagement in cognitive training groups, and potential implications for cognitive remediation and psychotherapy (McKee et al., 1997; Lysaker et al., 2008). Research also identified EF as a crucial role in enhancing functional outcomes (Bowie & Harvey, 2006). On the one hand, our findings replicated prior research of EF deficits in schizophrenia, and could in this sense, support the importance of enhancing EF in order to improve treatment success and the variety of functional outcomes in individuals with non-chronic schizophrenia. Contrary to what limited research has suggested, our findings imply that hot EF is not as important for social functioning impairments as cool EF.

On the other hand, this investigation may indicate that better performance on objective cool EF tasks is associated with poor self-reported social functioning. Furthermore, our findings may also indicate that better objective hot EF is associated with poor objective social functioning. If the findings are accurate, they pose ethical concerns. It may be problematic to improve objective EF if it leads to a decline in self-evaluated social functioning. Nonetheless, if the problem lies solely in how the individuals evaluate themselves and the social difficulties are not as impaired as subjectively reported, possibly because they do not want to be social, or if the SFS is not an accurate measure, it will be important to be aware of these factors and make any necessary accommodations in treatment.

4.4 Strengths, limitations and future research

Using both self-reports and clinician-based measures of social functioning is particularly advantageous since it provides a more comprehensive evaluation of the social functioning in individuals with schizophrenia. Objective measures enabled us to assess and measure the capability of the participants' executive skills, whereas subjective and more ecological measures revealed how participants apply these skills in real-world contexts (McAuley et al., 2010; Gioia et al., 2010; Bulzacka et al., 2013; Haugen et al., 2021). Additionally, the integration of multiple objective and subjective measures of hot and cool EF is beneficial for a thorough exploration of the many executive functioning components. Although this study gives a more nuanced perspective of the variety of EF difficulties in schizophrenia and their association with social functioning via the hot-cool and objective-subjective dichotomies. The findings of this study should be interpreted with caution, as there are some methodological limitations.

Firstly, as this study was a cross-sectional study, we could not establish the direction of the causation of the association between EF and social functioning. Secondly, it may be problematic to use subjective ratings, such as the SFS and the BRIEF-A. Subjective measurements provide meaningful information about the application of executive skills in everyday life in individuals with schizophrenia, but their accuracy and validity may be confounded by emotional states, demand characteristics, social desirability bias, lack of insight, or cognitive impairment (McCambridge et al., 2012; Harvey & Pinkham, 2015; Shwartz et al., 2020). However, the SFS and the BRIEF-A are still regarded as ecologically valid measures of an individual's own assessment of their functioning, and were therefore included in our study (Birchwood et al., 1990, Roth et al., 2005; Garlinghouse et al., 2010, Bulzacka et al., 2013). Further, the GAF has been criticised for being overly unidimensional and challenging to interpret (Burns & Patrick, 2007). This measure's interpretability and generalizability may be limited by the fact that it was done by multiple persons. There is however evidence advocating for clinician-based assessments of social functioning and the validity of GAF, and was therefore included in our study (Pedersen et al., 2007; Aas, 2010; Harvey & Pinkham, 2015).

Using all four objective cool EF tests (CWIT3; CWIT4; Tower Test; Letter-Number Sequencing), a composite score was created to increase the statistical power of the measure. The use of a composite score was justified by the fact that prior studies have advocated the use of composite scores (Kaneda et al., 2007; Crane et al., 2008). Although the correlations between the four cool EF tests were low (r = .12 to .69), previous research has also reported low correlations between EF tasks, and this diversity is thought to be characteristic for a construct of this complexity (Friedman & Miyake, 2017). The use of a composite score with all the objective measures of cool EF in our study, is thought to make the score more robust, in integrating the different components of cool EF (*inhibition*, *shifting*, and *updating).*

When it comes to IGT, it is essential to recognise the methodological complexity of the task, since there are a range of underlying processes that can affect the task's outcome (Gansler et al., 2011; Bagneux et al., 2013). However, the task is a highly valuable research paradigm since it allows us to investigate the relation between emotion and cognition (Stocco et al., 2009). In addition, IGT is widely recognised as a valid and concise measure of EF due to its capacity to assess *decision-making* (Bechara et al., 1997; Kerr & Zelazo, 2004; Zelazo & Carlson, 2012; Goldstein et al., 2014; Zinchenko & Enikolopova, 2017).

In this study, norms were employed as a basis for comparison rather than healthy controls, as the data were collected from a treatment-study. For a more representative comparison, additional studies might include a healthy control group. Another limitation was some missing data for the BRIEF-A and SFS questionnaires, because some of the participants were allowed to fill out questionnaires from home, due to long assessment days. The missing data is assumed to be missing at random and there were no significant differences in performance on the assessments found between participants that returned questionnaires and those who did not. In addition, a small number of participants did not complete all the objective tasks, for example due to colour-blindness.

Generalisability of findings

Our findings can be generalised to a broad population of individuals with schizophrenia. The sample consisted of 65 individuals with schizophrenia spectrum disorders, with a mean age of 25, having not received treatment for more than five years. The sample also consisted of 26 females (40%) and 39 males (60%). Therefore, our group represents a relatively young, non-chronic subset of individuals with schizophrenia spectrum disorder. Furthermore, the inclusion of individuals diagnosed with a schizophrenia spectrum disorder makes the sample somewhat heterogeneous. Twenty-nine individuals were diagnosed with schizophrenia according to the DSM-IV definition. However, deficits in executive functioning are seen as a basic feature, not only of schizophrenia, but of all the schizophrenia spectrum disorders (Sanchez-Torres et al., 2013).

Future directions

According to the findings and limitations of this study, it would be appropriate for future studies to include measures of "self-criticism" and "insight into cognition". The focus of future studies should be on expanding the understanding of both hot and cool executive functioning and emphasising the significance of several hot EF tasks. Future research should expand the understanding of the association between EF and social functioning by adding numerous or additional social functioning measures. Consequently, future research should include a measure that investigates the gap between objective and subjective reports, as well as an objective assessment of social functioning that is less susceptible to bias. In addition, it could be of importance to study the role of social cognition as a confounding, intermediate variable between executive and social functioning. It could also be of relevance to account for the employment status, living condition, and relationship status of the individuals. This thesis did not account for these subgroups due to their small sizes and lack of statistical power to explain interactions. To deepen the understanding of the association between EF and social functioning, it would be beneficial to increase the number of participants and investigate how it manifests in individuals with chronic, long-lasting schizophrenia.

4.5 Conclusion

The present cand.psychol. thesis indicates that individuals with schizophrenia have difficulties on both hot and cool EF. Interestingly, individuals with better objective cool EF report more social difficulties. Self-criticism, insight-related difficulties, and the avoidance of negative occurrences are all possible explanations for this unexpected association. Those with a better objective cool EF may compare themselves to healthier individuals based on prior social relationships, whereas those with a lower objective cool EF may have less social experience and thus a smaller basis for comparison. Although the inclusion of objective hot EF increased the explanatory power of EF on objective social functioning, our findings suggest that hot EF is not as important for impairments in social functioning as initially thought. Clinicians tend to assess individuals with a better objective hot EF as having a lower social functioning. Individuals with schizophrenia may benefit from traits like risk-seeking and impulsivity because they are more likely to seek out social relationships. Given that some of our findings contradicted our expectations, more knowledge is needed. In addition, understanding the complexity of EF, may contribute to targeted interventions that may improve social functioning for individuals with schizophrenia. Focusing on increasing social functioning in individuals with schizophrenia may be of importance, considering the negative impact of poor social functioning on these individuals' quality of life. A better understanding of the underlying factors of executive and social functioning in individuals with schizophrenia may contribute to further research on social functioning interventions.

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