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ΤΜΗΜΑ ΦΙΛΟΛΟΓΙΑΣ
ΤΜΗΜΑ ΨΥΧΟΛΟΓΙΑΣ

Ξανθή Καμώνα

Α. Μ. 17Μ04

The role of verbal and non-verbal working memory in the comprehension of subject and object relative clauses in Greek high-functioning children with ASD: a theoretical approach on underconnectivity theory.

Διπλωματική εργασία
για τη λήψη μεταπτυχιακού διπλώματος ειδίκευσης από το
Διατμηματικό Πρόγραμμα Μεταπτυχιακών Σπουδών στη Γνωσιακή Επιστήμη

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Σπυριδούλα Βαρλοκώστα, Καθηγήτρια, ΕΚΠΑ
Πέτρος Ρούσσος, Αναπληρωτής Καθηγητής, ΕΚΠΑ
Ειρήνη Σκαλιόρα, Καθηγήτρια, ΕΚΠΑ

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Εγκρίνεται η διπλωματική εργασία

Σπυριδούλα Βαρλοκώστα ....

Πέτρος Ρούσσος ....

Ειρήνη Σκαλιόρα ....

Περίληψη

Η Διαταραχή Αυτιστικού Φάσματος (ΔΑΦ) αποτελεί μία διάχυτη νευροαναπτυξιακή διαταραχή η οποία χαρακτηρίζεται κυρίως από περιορισμένες κοινωνικές και επικοινωνιακές δεξιότητες καθώς και από στερεοτυπικές και περιορισμένες συμπεριφορές και ενδιαφέροντα (DSM-V). Εκτός από τη θεωρία της Αδύναμης Κεντρικής Συνοχής και την απώλεια της Θεωρίας του Νου (Frith and Happé, 1994), ελλείμματα έχουν παρατηρηθεί και στις επιτελικές λειτουργίες σε παιδιά με ΔΑΦ (Hughes et al. 1994; Pennington and Ozonoff, 1996; Hill, 2004). Η εργαζόμενη μνήμη επιτρέπει την προσωρινή αποθήκευση και επεξεργασία πληροφοριών και εδρεύει κυρίως στα μετωπιαία-βρεγματικά δίκτυα του εγκεφάλου. Τα αποτελέσματα ερευνών σχετικά με την εργαζόμενη μνήμη των παιδιών με ΔΑΦ είναι αμφιλεγόμενα, καθώς οι ερευνητές υποστηρίζουν τόσο την ύπαρξη όσο και την απώλεια ελλειμμάτων σε διάφορες πτυχές της (Bennetto, Pennington, & Rogers, 1996). Ωστόσο, ένα από τα βασικότερα ευρήματα αναφορικά με τα ελλείμματα στην εργαζόμενη μνήμη σχετίζεται με το φορτίο και την πολυπλοκότητα της πληροφορίας προς επεξεργασία. Όσο πιο περίπλοκη είναι η πληροφορία που τίθεται σε επεξεργασία, τόσο πιο δύσκολη καθίσταται η επεξεργασία της από τα παιδιά με ΔΑΦ. Επιπλέον, η αναχαίτιση -ή αλλιώς ο ανασταλτικός έλεγχος- δηλαδή η ικανότητα του ατόμου να ελέγχει τη συμπεριφορά του αποκλείοντας εξωτερικά ερεθίσματα, αποτελεί μία από τις επιτελικές λειτουργίες που έχουν μελετηθεί σε παιδιά με ΔΑΦ. Εντούτοις, ελάχιστες έρευνες έχουν μελετήσει τη συσχέτιση μεταξύ των ελλειμμάτων στην εργαζόμενη μνήμη και την αναχαίτιση και των γλωσσικών ελλειμμάτων που μπορεί να παρουσιάζουν τα παιδιά με ΔΑΦ. Η παρούσα έρευνα θα μελετήσει τα πιθανά ελλείμματα στη λεκτική εργαζόμενη μνήμη μέσω μίας δοκιμασίας αντίστροφης ανάκλησης ψηφίων, όπως και στην αναχαίτιση μέσω δύο αντίστοιχων δοκιμασιών σε ελληνόφωνα παιδιά υψηλής λειτουργικότητας με ΔΑΦ (ηλικίες 7 – 11 ετών), καθώς και σε παιδιά τυπικής ανάπτυξης της ίδιας ηλικίας. Επίσης, η εν λόγω έρευνα θα μελετήσει την κατανόηση των αναφορικών προτάσεων Υποκειμένου και Αντικειμένου στους ίδιους συμμετέχοντες μέσω μίας δοκιμασίας επιλογής εικόνας. Τέλος, θα παρουσιαστεί σε θεωρητικό επίπεδο η νευρωνική βάση του ελλείμματος στην εργαζόμενη μνήμη και στη γλώσσα, η οποία βασίζεται στη θεωρία της υποσυνδεσιμότητας που παρατηρείται στα άτομα με ΔΑΦ (Just et al., 2004).

Λέξεις κλειδιά: Διαταραχή Αυτιστικού Φάσματος, επιτελικές λειτουργίες, εργαζόμενη μνήμη, αναχαίτιση, αναφορικές προτάσεις Υποκειμένου και Αντικειμένου

Abstract

Autism Spectrum Disorder (ASD) is a pervasive neurodevelopmental disorder characterized mainly by diminished social and communicational skills and the presence of stereotyped and restricted behaviors and interests (DSM-V). Apart from a weak central coherence account and an absence of Theory of Mind (Frith and Happé, 1994), executive function impairments are also common in ASD (Hughes et al. 1994; Pennington and Ozonoff, 1996; Hill, 2004). Working memory allows for temporary storage and manipulation of information and relies heavily on frontal-parietal networks of the brain. Research on the deficit in working memory in children with ASD is controversial, as there are suggestions about either intact or impaired aspects of working memory (Bennetto, Pennington, & Rogers, 1996). However, one of the main findings is that deficits in working memory might be associated with the load and complexity of information that needs to be processed. The more complex the information is, the more difficult it is to be processed by children with ASD. Also, inhibitory control, the ability to delay a behavioral response, has been studied in children with ASD. Little research has shown the correlation of working memory and inhibition deficits with language difficulties that children with ASD might present. This study will try to shed light on verbal working memory deficits through a digit backward task along with two inhibition tasks in high-functioning children with ASD (aged 7-11 years old) and typically developing children matched on chronological age, combined with a language task based on the comprehension of subject and object relative clauses in Greek. Moreover, the present study will try to provide a theoretical background of the neural basis of disordered working memory and language, related to neurobiological foundations of underconnectivity in ASD (Just et al., 2004).

Keywords: Autism Spectrum Disorder, executive functions, working memory, inhibition, subject and object relative clauses

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1. Introduction

The nature of Executive Functions (EFs) of children with Autism Spectrum Disorder (ASD) has been widely studied over the past years. It is of grave significance to identify the specific aspects of these cognitive processes that help people deal with aspects of everyday life. Even though EFs, especially Working Memory and inhibition, have been in the center of attention for many researchers, it still remains unclear what is the exact nature of these functions in ASD children. Based on the disparity of evidence among researchers as far as these two core EFs are concerned, this study will try to explore them in order to help elucidate their exact nature in ASD children.

Furthermore, it is widely known that ASD children face communication and language problems. The main concern of those who work with ASD children is to be able to recognize and understand the nature of the possible linguistic impairments these children might present in order to form the most suitable intervention for them. Syntactic impairments seem to be very common among the ASD population. The present study examines one aspect of syntax, the comprehension of subject and object Relative Clauses. Based on previous studies that were conducted in children with other neurodevelopmental disorders on this topic, data for the comprehension of these structures in Greek-speaking ASD children seem to be scarce. As a result, conducting research on this topic will provide us with further evidence as to the comprehension of these specific structures by ASD children.

Therefore, the purpose of the current study is to examine both the nature of Working Memory and inhibition – two major EFs – along with the comprehension of subject and object Relative Clauses in Greek-speaking ASD children. The ASD population chosen for the current study consists of verbal and high-functioning children (HFA), with a good level of communication and language. However, both the aforementioned EFs and the comprehension of the relative clauses follow a specific developmental trajectory. Thus, we assume that it is worth studying their nature in typically-developing children, as well, by comparing the performance of the two groups. In particular, the comprehension of both subject and object RCs constitutes a complex domain of syntax which is acquired by children approximately at the age of 5 and 6 (Hakansoon & Hansson, 2000). Hence, it is considered vital to examine the comprehension of these structures both in TD and ASD Greek-speaking children.

The first chapter of the present study constitutes the introduction, where the basic topics are presented followed by a brief analysis of each chapter.

Chapter 2 of the study discusses the theoretical background along with a bibliographical review of studies on which the present study was based. It starts with the definition of ASD and its diagnostic criteria in section 2.1, followed by the factors that contribute to its presence in section 2.2, dividing them into genetic and environmental.

The following section of the study (2.3) includes some basic definitions and terms, beginning with an extensive discussion on EFs in general in subsection 2.3.1 and moving to the definition and discussion of the two EFs studied, Working Memory and inhibition. Then, in subsection 2.3.4 the relationship between these two EFs is discussed.

Following the main definitions, in section 2.4 we present specific studies on the nature of all EFs in ASD children, followed by studies concerning Working Memory and inhibition in ASD in sections 2.4.1 and 2.4.2 respectively. All these parts draw a distinction between the studies that have found an impairment in these EFs and those which have supported that EFs in ASD individuals follow a normal trajectory similar to that of typically-developing children.

Section 2.5 discusses the linguistic profile of ASD children and the impairments they might present in different domains of language. Then, in subsection 2.5.1 we focus on the grammatical aspects of language, mainly on syntax, before we move onto the acquisition of Relative Clauses. The acquisition of these structures is first discussed in section 2.6 under the light of typical development, based on the Relativized Minimality theory (Rizzi, 1990; 2004, 2013) and the different levels of difficulty of these structures (Durrleman, Marinis & Franck, 2016). After that, in subsection 2.6.2 a small number of studies on the comprehension of RCs in ASD children are presented, due to the scarcity of evidence concerning these structures.

Then, in section 2.7, the relationship between EFs and language in ASD is presented in order to discuss any correlations between these two cognitive domains and the influence that EFs might exert on language development.

The last chapter of the theoretical background (chapter 2.8) consists of a literature review on neural underconnectivity theory in ASD (Just et al., 2004). It is important to note here that this is the only part of the present study that will not be investigated experimentally due to time and resource restrictions.

In chapter 3, the current study is presented. Firstly, in section 3.1 we present the purpose of the current study which is to examine the nature of Working Memory and inhibition as well as the comprehension of subject and object Relative Clauses in TD and ASD children. Afterwards, in section 3.2, the specific hypotheses of the present study are given, based on the lack of agreement concerning EFs in ASD population, along with the lack of data concerning the comprehension of RCs in Greek-speaking TD and ASD children.

Further, section 3.3 describes the methodology of the study, including information about the participants, the materials used, as well as the experimental procedure that was followed. In chapter 4, the procedure that was followed with scoring and data analysis is presented, followed by the results of the study in chapter 5.

Chapter 6 consists of the discussion of the results (section 6.1), as well as the limitations of the current study (section 6.2) and suggestions for future research (Section 6.3). Finally, the current thesis concludes with the References section on which the present study was based.

2. Theoretical Background

2.1 ASD definition and diagnostic criteria

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder which is characterized by persistent deficits in social communication and social interaction across multiple contexts on the one hand, as well as by restricted and repetitive patterns in behaviors, interests, and activities on the other hand (APA, 2013). These symptoms occur early in life and impair everyday functioning. However, they cannot be explained by global developmental delay or intellectual disabilities, although the latter frequently co-occur with ASD. According to DSM-V, verbal and nonverbal communicative impairments in individuals with ASD depend on diverse factors, such as chronological age, intellectual abilities, and treatment history. Along with the aforementioned deficits, ASD is also characterized by language impairment and/or delay, ranging from absence of speech to delays in language development, comprehension difficulties and use of overly literate language. Although the DSM-V states that formal linguistic features, such as vocabulary and grammar, might remain intact, the use of language for communicative purposes seems to be impaired in ASD. Some early studies showed that 50% of individuals with ASD never acquire functional speech (Prizant, 1996; Rapin, 1991), though more recent studies indicate a smaller proportion of nonverbal individuals with ASD, accounting for approximately 25% (Tager-Flusberg, Paul, & Lord, 2005). According to Eigsti (2011), these discrepancies might derive from methodological factors, such as the use of spontaneous tasks instead of structured ones.

In May 2013, the 5th edition of DSM (Diagnostic Statistical Manual of Mental Disorders) was released. In this edition, the definition Pervasive Developmental Disorder (PDD), which was used in the 4th edition of DSM (DSM-IV), is substituted by the umbrella term "Autism Spectrum Disorder" (ASD). Under this term, other categorical subgroups have been placed, such as "Autistic Disorder" (AD), "Asperger's syndrome" (AS), "Pervasive Developmental Disorder not otherwise specified" (PDD-NOS) and "Childhood Disintegrative Disorder" (CDD) (Lai, Lombardo, Chakrabati, & Baron-Cohen, 2013). The recognition of the "spectrum" nature in autism has been of great value, as it has facilitated our understanding towards the heterogeneity in the presentation and severity of ASD symptoms, as well as in the skills and level of functioning of individuals with ASD (APA, 2013). When we refer to the term "spectrum", we mean that the symptoms of the aforementioned disorders constitute a uniform continuum of disorders, which mainly concern the field of social interaction as well as that of a restricted and repetitive pattern of behaviors and are no longer considered as separate disorders.

DSM-V supports a division of ASD in two behavioral domains: difficulties in social communication and interaction and unusually restricted, repetitive behaviors and interests. The first domain, the one concerning difficulties in social communication and interaction, includes deficits in social-emotional reciprocity, abnormal social approach, difficulty in starting, maintaining or responding to social interactions, as well as poor verbal and nonverbal communication, ranging from abnormalities in eye contact and body language to deficits in the understanding and use of gestures (APA, 2013). In addition, deficits in understanding relationships, adjusting behavior to suit variable contexts, and absence of interest in peers are also part of the social communication deficit which is core in people with ASD (APA, 2013). As far as the second domain is concerned, the one that has to do with restricted and repetitive patterns of behavior, interests, or activities, this is manifested through stereotyped or repetitive motor movements, echolalia, or use of idiosyncratic phrases. Moreover, inflexibility to adhere to routines, insistence on sameness, and fixated interests, which are abnormal in intensity or focus, are also evident in ASD (APA, 2013).

However, there are different levels of severity in ASD. According to DSM-V, there are 3 different levels based on both social communication deficits and restricted and repetitive patterns of behavior and interests. Level 3, which requires very substantial support, is mainly characterized by severe deficits in verbal and nonverbal social communication skills, very limited initiation of social interactions, and minimal response to social overtures from others (APA, 2013). Level 2, which requires substantial support, presents marked deficits in verbal and nonverbal communication, limited initiation of social interactions, and reduced or abnormal responses to social overtures from others (APA, 2013). The interaction is limited to narrow special interests and the nonverbal communication is markedly odd. Level 1, which requires a smaller amount of support, consists of difficulty in initiating social interactions, as well as atypical or unsuccessful response to social overtures from others. Sometimes decreased interest in social interactions is also evident (APA, 2013).

Many theories were proposed to explain the deficits and nature of ASD. One main theory is the Theory of Mind deficit (ToM), which states that individuals with ASD do not have the ability to mentalize or infer others' mental states (Baron-Cohen, Leslie & Frith, 1985). Another prominent theory is the weak central coherence theory which supports that individuals with ASD tend to process parts of detail information of things rather than their global meaning (Frith, 1989). Lastly, the Executive Function theory states that the most abnormalities of individuals with ASD are related to executive dysfunction– a notion that will be further discussed later on in this study – (Hill, 2004). Among these theories, Executive Dysfunction theory can account for many of the non-social aspects of autism, and it is the only theory that acknowledges both cognitive and motor aspects of ASD (Rajendran & Mitchell, 2007).

However, the main distinction that has been drawn is that between Low-Functioning Autism (LFA) and High-Functioning Autism (HFA), dividing ASD in two broader levels. This division has been made taking into consideration the IQ level of the individuals with ASD. More specifically, persons with ASD who have an IQ level higher than 70 belong to the High-Functioning Autistic group, while those who have an IQ level lower than 69 are considered to be part of the Low-Functioning Autistic group (deGianbattista et al., 2019).

2.2 Contributing factors to the presence of ASD

2.2.1 Genetic factors

The past years, there has been extensive research trying to verify the factors which contribute to the presence of ASD. These can be divided mainly into genetic and environmental ones. According to Kolevzon, Gross, & Reichenberg (2007), advanced paternal and maternal age is considered as a risk factor for ASD, along with obstetric conditions, such as birth weight and gestational age at birth and intrapartum hypoxia.

Another genetic risk factor for the presence of ASD is the fragile X mental retardation gene (FMR1), otherwise called the "Fragile X Syndrome". The FMR1 gene causes abnormalities in long-term synaptic plasticity of excitatory synapses and can, thus, cause the brain to develop in an abnormal way. As a result, FXS can be an underlying neurological substrate of autism (Benvenuto, 2009).

Furthermore, Tuberous sclerosis complex (TSC) can also lead to the development of ASD. TSC is an inherited disorder stemming from mutations in genes TSC1 (Hamartin) and TCS2 (Tuberin), which is commonly associated with other neuropsychiatric complications like epilepsy or mental retardation. More specifically, the TSC 1 locus 9q34 is considered as a significant region of vulnerability for the development of autism (Benvenuto, 2009).

Furthermore, some specific genes might be considered as a likely cause for autism. In particular, genes NLGN3, NLGN4, and NRXN1 are said to have undergone mutations in individuals with ASD (Lintas & Persico, 2009; Caglayan, 2010). Also, research has shown that there is a correlation between a mutated structure of the genes SHANK3 and PTEN (Caglayan, 2010) as well as the gene HOXA1, which was the first gene to be traced and related to the presence of autism (Rodier, 2000).

A great number of cytogenetic abnormalities, particularly in low-functioning autism, can also be a potential source of ASD. In particular, duplications in Chromosome 15 characterize people with ataxia, language delay, epilepsy or mental retardation, along with dysmorphic features, rendering these chromosomal rearrangements a likely cause for ASD (Dykens, Sutcliffe & Levitt, 2004; Benvenuto, 2009). Increased risk for autism can also be attributed to functional polymorphism in the MET gene as well as in the RELN gene, both playing a vital role in the development of neural connections, mainly in the cerebral cortex and the cerebellum (Benvenuto, 2009). Lastly, microdeletions in chromosomes 16 (16p11.2) and 2 (2q37) have been observed in some individuals with autism, adding to the plethora of genetic factors linked with ASD (Benvenutto, 2009).

2.2.2 Environmental factors

There has been great controversy over whether environmental factors can actually constitute risk factors for the presence of ASD. The past few years, there has been a steady and highly significant increase of estimates of the total prevalence of ASD. To name one recent example, the last prevalence estimates in the United States, released by the Centers for Disease Control, reached 1 in 88 children in 2008, while the previous estimate was 1 in 110 in 2006 (Prevalence of autism spectrum disorders--Autism and Developmental Disabilities Monitoring Network, 14 sites, United States, 2008). This result can be mainly attributed to the enlargement of diagnostic criteria and the growing importance of screening for ASD. It seems reasonable to think that there may be both a real increase in the number of cases as well as an increase in the detection of affected children. Nevertheless, these reasons could not be confirmed nor excluded definitively.

Some environmental factors that can contribute to the presence of ASD could be the exposure to drugs or toxic substances during pregnancy. Prenatal exposure to valproate is a recognized factor for ASD, especially in the first semester of pregnancy, as children have eightfold increased risk to have ASD (Rasalam et al., 2005). It is also suggested that antidepressant exposure during pregnancy modestly increases the risk of ASD, mainly during the first semester (Koloszi et al., 2009). In addition, exposure to an organophosphate insecticide, chlopyrifos, was found to increase ASD risk (Landrigan, 2010). Finally, exposure to heavy metals and xenobiotics create oxidative stress, which is evident to people with ASD. In turn, oxidative stress leads to impaired methylation and neurological deficits along with reductions in the capacity for synchronizing neural networks (Deth, 2007).

To sum up, we need to note that the aforementioned environmental factors have not been widely and experimentally examined as main causes of ASD, thus they need to be carefully considered.

2.3 Basic definitions and terms

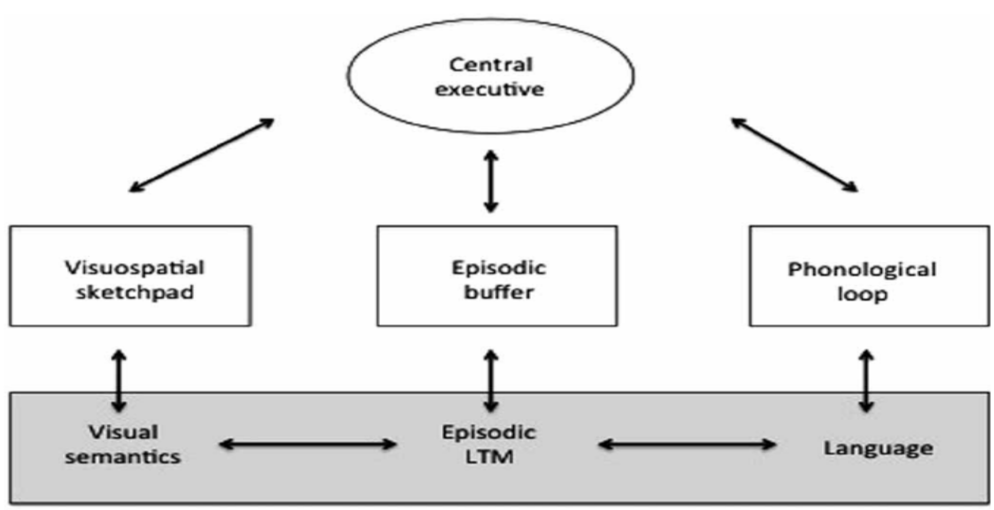
2.3.1 Executive functions (EF)

A common definition describes Executive Function (hereafter EF) as "the ability to maintain an appropriate problem solving set for attainment of a future goal" (Ozonoff, Pennington, & Rogers, 1991). Another definition of EF describes it as "a complex set of cerebral processes that operate in non-routine situations and exert top-down, volitional control over cognition and behavior" (Daffner & Searl, 2008). In other words, Executive Function is an overarching term that refers to neuropsychological processes and a connection of brain processes that enable physical, cognitive, and emotional self-control (Corbett et al., 2009). It is also necessary to maintain effective goal-directed behavior (Welsh & Pennington, 1988). Executive function is used by many neuroscientists as an umbrella term, including a broad network of cognitive and behavioral skills and processes, such as working memory, inhibition, planning/problem-solving, set-shifting/switching, self-monitoring (or else initiation and monitoring of an action), and fluency (Pennington & Ozonoff, 1996). One central idea in the concept of EF is context-specific action selection mainly in the case of strongly competing, though context-inappropriate, responses. The other central idea is maximal constraint satisfaction in the selection of an action, which requires the integration of constraints from a plethora of other domains, such as perception, memory, motivation, or affect (Pennington & Ozonoff, 1996). Thus, executive functions are core to human cognition and, consequently, executive dysfunction has a great impact on daily life. Deficits in EF are often observed in neurodevelopmental disorders, such as autism, even though examining the specificity of EF deficits still remains blurry. Lastly, EF dysfunction is often assumed to be caused by a dysfunction or disruption of particular brain structures, such as the prefrontal lobes of the brain (Daffner & Searl, 2008; Dawson & Guare, 2004).

EF develops throughout childhood and adolescence among typically developing individuals. However, EF dysfunctions are evident in neurodevelopmental disorders and are a main characteristic in individuals with ASD. Nevertheless, some methodological issues arise when considering the charting of the development of EF processes among this population. The developmental level of participants, the selection of relevant matching measures, the choice of comparison participants, and the ways that levels of EF are attained are among the main reasons that raise these methodological concerns (Russo et al., 2007). In particular, the performance of individuals with autism may be impaired for some components of EF and not for some others, at some points of development and not at others, and in relation to some matching measures or some comparison groups but not others. For example, inhibition abilities seem to be unimpaired when inhibition is the only EF examined and does not interfere with other EF measurements and when participants are older than 6 years. On the contrary, WM deficits among individuals with autism seem to be more complex as in later childhood and adolescence some WM measurements, for example WM span, are impaired while measures of interference are not. Cognitive flexibility, on the other hand, is highly impaired during adolescence and adulthood in ASD population, with evidence supporting impairments in younger developmental stages, as well. These developmental patterns suggest that EF processes and deficits are dynamic and prone to change and need to be considered carefully within a framework of developmental theory and methodology (Russo et al., 2007).

2.3.2 Working Memory (WM)

One of the core components of EF is Working Memory (hereafter WM). WM is considered to be a temporary storage system under attentional control which serves as a basis for human capacity for complex thought and cognitive activities (Baddeley, 2012). In broader terms, it has been proposed that WM is the ability to temporarily store and simultaneously manipulate information (Baddeley, 2003). As first proposed by Baddeley and Hitch (1974), the Working Memory model consists of three components: a phonological or articulatory loop which is responsible for storing verbal and acoustic information, the visuospatial sketchpad dealing with storing visual and spatial information, and the central executive, on which both the aforementioned components depend, which is an attentionally-limited control system that is assumed to control behavior (Baddeley, 2001). The central executive (CE) component is a domain-general attention-allocation mechanism that controls and coordinates different activities within WM (Weismer, 2017). Control functions comprising the CE include selective attention, inhibition, allocating and shifting attentional resources, updating information, and coordinating multiple tasks (Baddeley, 1996). Thus, the two types of WM are distinguished by content – verbal WM and non-verbal (visuospatial) WM. Baddeley (2000) proposed a fourth component of the Working Memory system called the episodic buffer. This refers to a limited capacity system that depends highly on executive processing, but it differs from the central executive system in that it is primarily concerned with the storage of information rather than with attentional control (Baddeley, 2000). More specifically, it is capable of binding together information drawn from different sources into chunks or episodes. In fact, it combines information from different modalities into a single multi-faceted code, and it is also believed to underpin the capacity for conscious awareness (Baddeley, 2000). For a schematic view of Baddeley's revised model see picture 1.



Picture 2.1 Baddeley's revised model of Working Memory (Baddeley, 2000)

Consequently, WM plays a crucial role in supporting numerous cognitive abilities with high complexity, such as language comprehension. If we take into consideration the fact that WM is a temporary storage system that reinforces our capacity for thinking, then it seems likely that it can also affect language processing, and that disorders in WM may have an impact on language processes. Particularly, deficits within the phonological loop may seriously affect or even impair language processing, along with other aspects of WM, which seem to play a less vital role in language processing and its potential impairment (Baddeley, 2003).

Although Baddeley (1986) used the term WM to refer mainly to the verbal short term memory portion of a WM system, it is worth stating that Pennington (1994) focused more on the executive portion of WM. He defined WM as "a limited capacity computational arena. Its key characteristics are (1) *action selection*, which operates through dynamic process of (2) *constraint satisfaction*, which must necessarily be (3) *context-specific* and *transient*." According to this view, the WM system allows a person to temporarily hold on-line constraints relevant to the current context in order for these constraints to lead to adaptive action selection (Pennington and Ozonoff, 1996). The aforementioned constraints can include the current environments and the person's current motivational state, goals, and plans retrieved from long-term memory (LTM), as well as other type of information retrieved from LTM (Pennington & Ozonoff, 1996). It is also important to mention that, apart from holding and manipulating information in WM, updating information plays a crucial role. Updating information refers to the ability to encode information and replace it when it is no longer relevant to the task (Morris & Jones, 1990).

To conclude, it could be argued that WM constitutes one of the major components of EF as it underlies many other cognitive processes, making the need for further research even more conspicuous.

2.3.3 Inhibition

One of the five core domains of EF as stated by Pennington and Ozonoff (1996) is inhibition. Inhibitory control, or else inhibition, involves being able to control one's attention, behavior, thoughts, and/or emotions to override strong internal predisposition or external lure, and instead do what is appropriate or needed in a specific context (Diamond, 2013). Another definition of inhibition was given by Barkley (1997a, b) who defined it as the ability to delay a behavioral response. Whereas inhibition is often discussed as a unitary construct, it is considered to be multifaceted (Aron, 2011; Friedman & Miyake, 2004; Nigg, 2000). One subdivision of inhibition is the so called cognitive inhibition, which means suppressing prepotent mental representations (Diamond, 2013). It involves resisting extraneous or unwanted thoughts or memories, like intentional forgetting (Anderson & Levy, 2009), resisting proactive interference from information acquired earlier (Postle et al. 2004), and resisting retroactive interference from items presented later. The ability to deliberately inhibit a dominant, automatic, or prepotent response when it is necessary and/or requested is called response inhibition and acts at the level of behavior (Miyake et al., 2000). This ability is defined as the capacity to withhold an ongoing response that is no longer relevant. Executive attention is also another category of inhibition that functions at the level of attention (Diamond, 2013).

Cognitive inhibition plays the role of aiding WM and it seems to cohere more with WM measures (Diamond, 2013). Nonetheless, inhibition can be viewed as a totally independent executive function from WM. However, these two functions do not necessarily need to be mediated by separate cognitive mechanisms. Inhibition is an intrinsic property of a WM system (Cohen & Servan-Schreiber, 1992; Kimberg & Farah, 1993). Increased activation of WM processes inhibits the activations required for competing response outcomes. In broader terms, competitive dynamics in the WM system and in its connection with other systems determine which response will be selected: either one that best fits the current context or one that is prepotent but constitutes a poor fit (Pennington & Ozonoff, 1996).

Different types of inhibition are assessed through different types of tasks. Prepotent response inhibition – the ability to suppress a dominant motor response and cancel the initiated response – is measured with tasks that require participants to respond as fast as possible to a majority of stimuli, while withholding (inhibiting) a response to a minority of stimuli, which are signaled by the presence of a specific stimulus (Geurts et al., 2014). Thus, participants have to completely countermand an initiated response in order to perform well in the task (Geurts et al., 2014). Some characteristic examples of the tasks used to measure prepotent response inhibition are the so called Stop tasks and Go/No-Go tasks (Logan et al., 1984). Nevertheless, tasks that resemble the widely used Stroop task (Stroop, 1935) – during which participants should focus on a specific aspect of a stimulus and ignore another aspect of the same stimulus – are considered to be appropriate measurements either of prepotent inhibition (Friedman & Miyake, 2004) or of interference control (Nigg, 2000). Interference control, or else resistance to distractor interference, is the efficiency with which an individual is able to ignore relevant information while processing target stimuli. The evaluation of these processes can be measured through tasks such as the Flanker task (Eriksen & Eriksen, 1974) and Simon paradigms (Simon & Wolf, 1963), as well as the Stop Signal Task (SST; Logan & Cowan, 1984). What is required of the participants in the aforementioned tasks is to respond to a stimulus as quickly as possible, while, at the same time, information that evokes an opposite response (incongruent information), or a similar response to the correct one, is presented. The difference between the prepotent inhibition tasks and the interference control tasks lies in the fact that in interference control tasks, inhibition is reflected by slower responses due to the conflicting or irrelevant/incongruent information (Friedman & Miyake, 2004; Miyake & Friedman, 2012; Nigg, 2000).

2.3.4 Relationship between Working Memory and Inhibition

As stated earlier, both WM and inhibition constitute core elements of EF, as has been suggested by numerous theories highlighting the importance of these processes (Barkley, 1997; Denckla, 1996; Diamond, Barnett, Thomas & Munro, 2007; Pennington, Bennetto, McAleerv & Roberts, 1996; Roberts & Pennington, 1996). They generally need one another and they often co-occur, making it difficult to need one instead of the other. More specifically, inhibition is supported by WM. An individual has to act contrary to his or her initial tendency on the basis of information held in mind, and this is the interface between those two EFs. One must hold a goal in mind in order to realize what action is relevant or appropriate or what action needs to be inhibited. Through focusing on the information that one is holding in mind, the likelihood that this information will guide one’s behavior increases and the likelihood of an inhibitory error (mistakenly emitting the default, or normally prepotent, response when it should have been inhibited) decreases (Diamond, 2013). As a result, WM cannot stand on its own without being assisted by inhibitory control.

Likewise, inhibition is in the service of WM. In order to relate multiple ideas or facts together, one must have the ability to resist focusing solely on just one thing or repeating previous thought patterns (Diamond, 2013). In other words, so as to keep one's mind focused on what is needed, one must inhibit both internal and external distractors. This leads directly to holding on-line information and protecting WM from becoming too cluttered as a mental workplace by suppressing extraneous thoughts (Diamond, 2013).

Even though WM and inhibitory control are two closely related EFs, a discrimination between the two is still possible, depending on the nature of the tasks administered. Some tasks, such as the Spatial Stroop task, place minimal demands on memory as the stimuli lead the participants to the place of response. Thus, the difficulty in performance lies mainly in inhibiting the prepotent tendency to respond on the same side as the stimulus (Diamond, 2013). On the other hand, reordering numerical or alphabetical items requires little attentional or response inhibition, thus making these type of tasks more appropriate measurements of WM (Diamond, 2013). Russell (1999, p.255) suggested that concurrent demands on inhibitory skills and WM processes are "two essential features of executive tasks". This means that, even though the task assesses another EF, all tasks implicate inhibition and WM to some degree (Booth, Boyle & Kelly, 2014).

The combination of the inhibition and WM within a single task may significantly increase the difficulty to perform the task, particularly for young children (Carlson, 2005). Some tasks, such as Delay gratification, are considered to be simple inhibition tasks as they do not pose great demand on WM. Conversely, tasks such as the Flanker task are believed to be complex inhibition tasks since the resolution of conflict between the dominant and subdominant responses is required, and, thus, they involve greater levels of top-down control (Garon et al., 2008). Lastly, two simulation studies (Cohen & Servan-Schreiber, 1992; Kimberg & Farah, 1993) have proven that the operation of WM may help to override prepotent but inaccurate responses. In order to deeply understand EF we need to take into consideration both the WM demand and the demand for inhibition (Pennington & Ozonoff, 1996).

To conclude, the significance of WM and inhibition among the rest of the EFs has been widely accepted since many theoretical and computational accounts of EF have further suggested that WM and inhibition may suffice to characterize the entire domain of EFs (Cohen & Servan-

Schreiber, 1992; Kimberg & Farah, 1993; Pennington, 1994; Pennington, Benneto, McAleer, & Roberts, 1996; Roberts, Hager, & Heron, 1994; Roberts & Pennington, 1996)

2.4 Executive functions in ASD

Many studies have approached Executive Functions as far as neurodevelopmental disorders are concerned, with autism being one of these. Since Rumsey's pioneering empirical work in 1985, Executive Functions in autism have been a topic of thorough investigation among researchers. However, the primacy of EF deficits in autism, especially in terms of planning, cognitive flexibility, inhibition, and working memory, remains debatable (Hill, 2004). Deficits in EF could explain many of the behavioral symptoms associated with autism, such as rigid and inflexible behavior, preservation, inappropriate responding in social situations, or lack of initiative and correctness in thought processes (Damasio & Maurer, 1978; Rumsey, 1985; Rutter, 1983). Below, we mention some important studies concerning the nature of different EFs in ASD population in order to elucidate their nature and form a more holistic approach on the EF deficits in this population, before we move onto research about WM and inhibition specifically.

A highly cited study by Ozonoff and Jensen (1999) compared the performance of children with ASD (aged 6-18 years, mean age = 12.6 years) with that of groups of typically developing children (TD), children with ADHD (Attention Deficit and Hyperactivity Disorder), and children with TS (Tourette Syndrome) concerning flexibility (Wisconsin Card Sorting Test - WSCT; Grant & Berg, 1948), planning capacities (Tower of Hanoi – TOH; Borys, Spitz & Dorans, 1982), and inhibition aspects (Stroop Color-Word Test; Stroop, 1935). The ASD group demonstrated difficulties on the flexibility and planning tasks, while performing normally on the inhibition test.

Moreover, Geurts et al. (2004) used a wide range of tasks related to five major domains of EFs, assessing the performance of HFA children (mean age = 9,4 years) compared to that of ADHD and TD children, matched on chronological age. In particular, they measured inhibition through the Change task (De Jong, Coles & Logan, 1995; Logan & Burkell, 1986; Ooosterlaan & Sergeant, 1998), the Circle Drawing task (Bachorowski & Newman, 1985, 1990), and the Opposite Worlds (TEA-ch; Manly et.al., 2001), Working Memory through the Self-Ordered pointing task – Abstract

Designs (SoP, Petrides & Milner, 1982), planning through the Tower of London (ToL; Krikorian, Bartok & Gay, 1994), flexibility through the Change task and the Wisconsin Card Sorting Test (WCST, Grant & Berg, 1948; Heaton, 1981; Heaton, Chelune, Talley, Key & Curtiss, 1993), and fluency through a Verbal fluency task, an adaptation of the Controlled Word Association Task (COWAT; Benton & Hamsher, 1978). They reported that children with HFA showed deficits across most EF measures, except interference and working memory, when compared to ADHD and TD participants. More specifically, they found difficulties in inhibiting a prepotent response, inhibiting an ongoing response, planning, cognitive flexibility, and verbal fluency in HFA children.

In addition, Golberg et al. (2005) conducted a series of experiments in order to assess the performance of ASD children compared to that of ADHD children and TD controls, all aged 8-12 years (mean age = 10.3 years). They measured response inhibition through the Stroop Color and Word test (Golden, 1978). They also measured the participants' abilities in problem-solving, set-shifting, and non-verbal memory, which were assessed using three tasks: the CANTAB (Cambridge Cognition, 1996), the Stockings of Cambridge Task, the Intra-Dimensional/Extra-Dimensional set-shifting task, and the Spatial Working Memory task, respectively. Their results showed no impairment in the ASD group as far as planning, set-shifting, and inhibition are concerned, but found statistically significant differences in the performance of ASD children in the spatial WM task, mainly when the complexity of the tasks increased, imposing a bigger cognitive load.

Nevertheless, research has found evidence of EF deficits in individuals with ASD across a wide range of chronological and mental ages (Verté, Geurts, Roeyers, Ooosterlaan & Sergeant, 2006). A great amount of research has also been conducted on deficits in the central-executive system in children with ASD (Ozonoff et al., 1991; Prior & Hoffman, 1990; Rumsey & Hamburger, 1988). More specifically, the central-executive system includes a variety of tasks, such as shifting between tasks, retrieving new strategies, inhibiting inappropriate reactions, and strengthening selective attention (Baltruschat, 2011).

Deficits in planning and set-shifting have been shown to be evident in individuals with ASD (Geurts et al., 2004; Ozonoff et al., 2004; Ozonoff & Strayer, 1997; Sergeant et al., 2002). Impairments in planning have also been recorded by numerous studies using the Tower of Hanoi task (Bennetto, Pennington & Rogers, 1996; Borys, Spitz & Dorans, 1982; Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994; Ozonoff, Pennington & Rogers, 1991). These studies measured the ability of planning in children with ASD compared to children with ADHD and TD children and showed that children with ASD performed worse than the other two groups.

Also, problem solving seems to be impaired in children with ASD as shown by studies measuring this particular EF (Alderson-Day, 2014). Moreover, Corbett et.al. (2009) suggested that there are impairments in 6 domains of EF (response inhibition, vigilance, WM, flexibility/shifting, planning, and fluency) in children with ASD when compared to children with ADHD and TD children.

To sum up, there seems to be a great divergence in the findings concerning EF in autism and further research needs to be conducted in order for safer conclusions to be reached. Considering distinct domains within EF might shed light on the nature of deficits in ASD and help address the specificity problem of EF accounts of ASD (Happé et al., 2006).

2.4.1 Working memory in ASD

Working Memory is one of the major components of EF and processes associated with it are needed in order to deal with many every-day tasks. More specifically, WM deficits are often evident in individuals with ASD, and mainly in children. However, there seems to be a disparity among the various findings, as many researchers support an impaired WM system, while others advocate for an intact WM system in ASD.

As mentioned earlier, according to Baddeley’s model of WM, there is a discrimination between the processing of verbal information (verbal WM), which is processed in the phonological/articulatory loop, and the processing of visual and spatial information (visuospatial WM), which is processed in the visuospatial sketchpad. Many studies have been conducted in order to clarify if there is an impairment or not in any of these areas. However, there is no consistency among the results due to methodological issues concerning matching (age, IQ, diagnostic criteria), the type of tasks administered (measuring WM maintenance, manipulation or both), or the cognitive processing or cognitive load, which means that the higher the complexity of the tasks, the worse the performance of the individuals with ASD.

Many studies have found a generalized impairment in the WM abilities of individuals with ASD, supporting the prominence of deficits in visual-spatial WM (Williams, Goldstein, Carpenter & Minshew, 2005; Williams et al., 2006). Also, WM deficits in individuals with ASD across a wide range of chronological and mental ages have been reported (Verté, Geurts, Roeyers, Ooosterlaan & Sergeant, 2006). Deficits in verbal WM have been showcased through tasks in which the recall of more complex verbal information, such as sentences and stories, was asked of the participants (Tager-Flusberg, 1995; Williams et al., 2006). These results can be associated with the influence of the central executive and long-term memory representations during the performance of complex tasks (Gathercole & Baddeley, 1993; Minshew & Goldstein, 1998; Tager-Flusberg, 1995; Williams, Goldstein, Carpenter & Minshew, 2005; Williams et al., 2006).

Firstly, we are going to focus on studies that have assessed verbal WM and discuss their conclusions. In particular, plenty of studies have supported an impairment in verbal WM in ASD in a wide range of chronological ages. Even though the study by Bennetto, Pennington & Rogers (1996) examined an older age group than the one examined in the present study, it is vital to mention it as it is one of the most cited studies concerning WM abilities in ASD. They assessed individuals with ASD, aged 11 to 24 years old (mean age = 15.95 years) who showed impaired WM abilities in two verbal WM span tasks (Sentence Span Task and Counting Span Task), which measured concurrent storage and processing of verbal information. The results in the Sentence Span Task could be attributed to deficits in understanding relevance (Frith & Happe, 1994) and the worse performance in the Counting Span Task could be attributed to the fact that participants had to hold onto the information over a long delay (Towse & Hitch, 1995).

Another highly cited study conducted on adolescents and young adults with ASD (mean age = 22.33) by Minshew & Goldstein (2001) reported impaired WM abilities in individuals with ASD as the complexity of the tasks increased. Particularly, there was a discrepancy in the performance of ASD participants compared to their TD counterparts in using organization to support recall on most of the CVLT (California Verbal Learning Test) trials.

Nevertheless, a great number of studies have examined the nature of verbal WM in younger ASD populations, yielding results that support a WM deficit. For example, Joseph, McGarth &

Tager-Flusberg (2005a) examined a group of ASD children (mean age = 7.11 years) and compared their performance to TD children (mean age = 8.3 years). They used a battery of tests to measure WM capacities, including a Word Span Forward and Backward task and a Block Span Forward and Backward task (Isaacs & Vargha-Khadem, 1989). They also examined WM and inhibitory control through numerous tasks (Day-Night; Gerstadt, Hong & Diamond, 1994; NEPSY Knock-Tap; Korkman, Kirk & Kemp, 1998). Planning abilities were also assessed through the NEPSY Tower task (Korkman et al., 1998). Their findings showed impairment in all three types of EF examined in ASD participants. Thus, these findings suggest that WM capacity in the ASD group was burdened by the additional requirement of manipulating information while holding it in mind, which supports the conclusion that the higher WM requirements are, the worse the performance is for ASD individuals.

Additionally, Gabig et al. (2008) tested young children with ASD (aged 5.0 to 7.11 years) and found a low performance of children with ASD in all measures of verbal WM (NWR = non-word repetition, MD = memory for digit span, SI = sentence imitation) in a hierarchical order. These results are in agreement with a pattern of escalating memory deficits with increasing task complexity.

Lastly, Schuh & Eigsti (2012) conducted a study in order to explore verbal and visuospatial WM in HFA children aged from 8 to 17 years old (mean age = 12.3 years) and age-matched TD children, by administering a set of both simple (non-word repetition task) and complex (Letter-Sequencing subtest from the Wechsler Intelligence Scale for Children – 4th edition) verbal WM tasks. The HFA group performed significantly worse than the TD controls across all tasks, suggesting a domain-general WM limitation in HFA, consistent with previous findings which reported deficits in short-term phonological WM (Whitehouse et al., 2008; Hooper et al., 2006), spatial WM (Williams et al., 2005; Williams et al., 2006), and more complex verbal WM (Bennetto, Pennington & Rogers, 1996; Poirier et al., 2011).

However, some studies have suggested that verbal WM remains intact in individuals with ASD pertaining to different age groups. To note some examples, Ozonoff & Strayer (2001) assessed young individuals with ASD, ranging in age from 7 to 18 years, and compared them with Tourette Syndrome (TS) individuals and typically developing children (TD) of the same age. The performance of the ASD group did not differ from that of the TD participants across the three tasks used in the study (Running Memory Task, Spatial Memory Span Task, Box Search Task), suggesting an intact WM system in youngsters with ASD. These results further support the notion that EF is a multidimensional category and that not all components are affected in autism (Ozonoff, 1977).

Moreover, Russell et al.'s (1996) findings were in agreement with those of Ozonoff & Strayer (2001) above. They measured WM performance of children with ASD (mean age = 12 years) and compared them to children with Moderate Learning Difficulties (MLD) and typically developing children (TD). Their results showed no significant difference among the three groups and ASD children did not show any specific impairments in the central executive of WM in tasks that require concurrent storage and processing.

Nonetheless, many studies have reported mixed results about verbal WM impairments in individuals with ASD, since participants showed impaired WM abilities in some tasks and intact WM abilities in others. This disparity is mainly attributed to the complexity of the tasks administered, as the more complex the task is, the worse the performance of ASD participants is.

For instance, Ham et al. (2011) examined a group of ASD children (mean age = 12.1 years) by using a digit recall task, a word list matching task, and a listening recall task, all of which measured verbal WM. The first two tasks measured maintenance of information in the WM system while the third one measured manipulation of information in WM. They found that participants with ASD did not significantly differ from the TD control group as far as performance on the digit recall test was concerned. However, ASD participants showed a poorer performance than their TD counterparts on the tests of word list matching and listening recall, as the stimuli presented were more complex, adding to the preponderance of findings which support that the high complexity of tasks causes a lower performance.

Mixed results about verbal WM impairments in individuals with ASD have also been found in a study by Williams, Goldstein & Minshew (2006), who reported poor memory in children with ASD, aged 8-16 years (mean age = 11.7 years), for both complex visual (Design Memory and Picture Memory) and complex verbal (Sentence Memory and Story Memory) stimuli. However, the same study found intact verbal WM (Number/Letter), a result that can be attributed to the low complexity of the latter task.

Moreover, Vogan et al. (2018) conducted a study over a group of children with ASD (mean age = 12.56 years) and age-matched TD controls, using a one-back letter matching task (LMT) with four different levels of difficulty to measure verbal WM. They found that ASD participants performed similarly to their TD counterparts in the first two simple levels of the task but had lower accuracy than the TD group in the two higher load conditions, suggesting that WM in children with ASD is similar to TD children for simpler tasks, but deficient for more complex tasks.

Intact WM abilities for simple tasks were also reported by Williams, Goldstein, Carpenter & Minshew (2005), when they examined a group of children with ASD (mean age = 11.75 years) using a variety of tasks to measure verbal WM. More specifically, they found unimpaired WM abilities in the verbal WM tasks (N-back Letter Task with baseline 0-back, 1-back, 2-back, Wide Range Assessment of Memory and Learning – WRALM; Sheslow & Adams, 1990; Number Letter Sequencing), as the stimuli and the instructions used in it were very simple. Also, the procedure followed in the N-back task places demand only on WM storage capacity and does not require a combination of problem solving and associated conceptual processes.

All the aforementioned results suggest that individuals with ASD demonstrate intact verbal WM abilities, allowing the use of the articulatory loop during the memory process. Their findings support the notion that individuals with ASD perform similarly to their TD counterparts in simple WM tasks that do not require a huge load on cognitive capacity. On the contrary, evidence suggests that deficient performance on complex cognitive and language tasks reflects inherent impairments in these abilities as has been proposed by the central coherence and complex information processing-underconnectivity models (Frith & Happe, 1994; Just et al., 2004; Minshew et al., 1997; Meyer, Meyer & Goldstein, 2002). Nevertheless, the disparity among the various findings makes the need for further research more salient.

One of the most widely used tasks to assess the verbal WM of ASD individuals is the Digit Span task, which constitutes part of the Wechsler Intelligence Scale for Children (WISC-revised; Wechsler, 1974). The task consists of the Digit Span Forward and the Digit Span Backward conditions. In the present study, the Digit Span Backward condition will be used as a verbal WM measurement. Thus, we provide below a few studies that used this task in order to get an insight into the results yielded through its use.

Faja & Dawson (2014) conducted a study in order to measure verbal WM through a Backward Digit Span task in ASD children (mean age = 7.3 years) and age-matched TD children. Their findings suggested that there was no difference between the performance of ASD children and TD children in the verbal WM task administered.

On the other hand, Schaeffer et al. (2018) examined a group of HFA children (mean age = 9.10 years) along with a group of children with SLI (Specific Language Impairment) and TD children matched on age. They measured the phonological memory of the participants through a Non-word repetition task (Rispens & Baker, 2012) and a Digit Span Forward task (WISC-revised; Wechsler, 1974). Verbal WM was assessed through a Digit Backward task (WISC-revised; Wechsler, 1974). They also administered the Odd-one-out task (Henry, 2001) to measure the abilities in nonverbal WM. The results showed that HFA children performed more poorly than the TD participants on phonological memory and verbal WM. However, the performance of HFA children in the nonverbal WM task did not differ from that of the TD children.

Therefore, it is assumed that, even when the same task is administered to ASD populations, results again seem to be divergent, implying that further understanding of the breakdown that occurs in verbal WM will provide a deeper insight into the neural basis of ASD.

As mentioned earlier, WM consists of a verbal and a spatial part. Even though the present study examines verbal WM, it is worth noting some studies which measured the abilities of ASD individuals in spatial WM in order to have a more complete approach on WM as a whole. The results concerning the nature of deficits in spatial WM in ASD population also seem to be divergent across a range of chronological ages.

For instance, Landa et al. (2005) examined EFs in and HFA school-aged group (ages ranging from 7 to 17 years, mean age = 11.01 years) and individually matched TD controls. Among the other CANTAB tests used, there was a Spatial Working Memory task in order to examine memory for visual-spatial locations. Indeed, the results showed an impairment of spatial WM and poor use of search strategies in children with ASD and the researchers concluded again that WM impairment is more conspicuous in complex tasks than in simple ones.

Similar results to those of Landa et al. (2005) were reached by other studies as well, thus advocating for an impaired spatial WM system in individuals with ASD (Steele et al., 2007;

McGonigle-Chalmers et al., 2008; Goldberg et al., 2005; Verte et al., 2005, 2006; Williams, Goldstein, Carpenter & Minshew, 2005; Williams et al., 2006; Happe et al., 2006; Russell et al., 1996; Zinke et al., 2010).

However, other studies have reported intact spatial WM abilities in ASD population (Ozonoff & Strayer, 2001; Geurts et al., 2004). The dissociation between intact and impaired spatial WM abilities can be attributed either to task complexity or to the nature of the tasks administered, as some spatial tasks are verbally mediated, since the stimuli facilitate the performance of the participants through verbal encoding of the information. This leads to an involvement of the use of the articulatory loop rather than of only the visuospatial sketchpad, leading to better performance by ASD individuals (Williams, Goldstein, Carpenter & Minshew, 2005).

As a result, it can be argued that research already conducted on the evaluation of WM abilities in ASD population has yielded diverse results, mainly due to methodological and matching issues. Hence, further research needs to be done in order to examine more thoroughly the nature of WM in autistic population.

2.4.2 Inhibition in ASD

As aforementioned, inhibition is one of the most prominent EF domains in which individuals with ASD seem to have impairments. However, there seem to be inconsistencies among the various findings, which arise due to methodological issues. The different nature of the tasks administered seems to play a crucial role in defining the nature of the difficulties that ASD children face as far as inhibitory control is concerned. Therefore, a discrimination between the tasks needs to be done in order to shed light on the specific aspects of inhibition that seem to be deficient in autism. The first type of the tasks deals with inhibiting a prepotent response, with various findings suggesting a significant impairment in this specific domain of inhibition. The second type of tasks is used to measure interference control, in which children with ASD also show a significant amount of impairment.

However, we are going to look at previous research conducted to assess the prepotent response inhibition and not interference control in individuals with ASD, as one of the purposes of the current study is to examine the nature of inhibiting a prepotent response Thus, we will start by looking at studies which found an impairment in this area and afterwards present the studies which did not find inhibition impairments among this population, followed by studies yielding mixed results due to task selection.

To begin with, Verte et al. (2006) reported poor inhibition of a prepotent and ongoing response in children with ASD (mean age = 9 years) when compared to their AS (Asperger's Syndrome) and PDDNOS (Pervasive Developmental Disorder not otherwise specified) counterparts. More specifically, they measured inhibition of a prepotent response as well as cognitive flexibility through the Change Task (De Jong, Coles & Logan, 1995; Logan & Burkell, 1986; Ooosterlaan & Sergeant, 1998). They also used the Circle Drawing task (Bachorowski & Newman, 1985, 1990) as a measure of inhibition of an ongoing response. Lastly, through the use of the Test of Everyday Attention for Children, Subtest Opposite Worlds (TEA-Ch; Manly et al., 2001), they assessed the participants' inhibition abilities and more specifically those of interference control. These results are in agreement with a previous study by the same authors, who reported difficulties in inhibiting a prepotent and ongoing response as well as in interference control by ASD children of the same age (Verte et al., 2005).

A similar age group was examined by Geurts et al. (2004), who reported that response inhibition deficits were more prominent in children with ASD (mean age = 9.4 years) when compared to ADHD children, as measured through the same tests as in the previous study (Verte et al., 2006). Other studies have also found impairments in inhibiting a prepotent response in ages ranging from 9 to 12 years (Bishop & Norbury, 2005; Corbett & Constantine, 2006), as well as for older ASD children with ages ranging from 12 to 15 years (Johnson et al., 2007; Ozonoff et al., 1994; Ames & Jarrold, 2007; Sinzig et al., 2008).

However, a few studies have suggested that there is no significant deficit in ASD individuals as far as inhibiting a prepotent response is concerned. The Stroop task is considered as one of the most widely used tasks to measure the response inhibition of children with autism.

Goldberg et al. (2005) measured the ability of inhibition in a group of ASD children (mean age = 10.3 years) through the Stroop task and Word task. However, contrary to previous studies, they did not find any significant impairment in response inhibition in ASD children when compared to TD participants. This disparity among the results can be attributed to the nature of the tasks, as both of the tasks administered were based on decoding verbal information. The researchers suggested that future studies focus more on non-verbal measures (Go/No-Go task, Stop-signal, ocular motor tasks) so as to exclude the factor of verbal WM interfering with performance in an inhibition task. Various other studies using this task showed that the performance of children with ASD aged from 6 to 18 years was equivalent to that of typically developing children, suggesting that the inhibitory capacity of children with ASD seems to follow a normal developmental trajectory (Eskes et al., 1990; Russell et al., 1999).

To continue, the studies that will be discussed below have found mixed results when they assessed the inhibitory control of ASD participants. This disparity is mainly attributed to methodological issues, as the nature of the tasks which were administered differed.

For instance, Happé et al. (2006) conducted a study over children with ASD (mean age = 10.9 years) and measured the inhibition and response selection of the participants through the Go/No-Go test, taken from the Maudsley Attention and Response Suppression (MARS) battery (Rubia et al., 2001). Their findings were mixed, as the ASD group did not show any significant impairment in inhibitory control, while it showed poor response selection/monitoring on the cognitive estimates part of the task.

Furthermore, Joseph et al. (2005a) utilized the Day-Night test (Gerstadt, Hong & Diamond, 1994) and the NEPSY Knock-Tap test (Korkman, Kirk & Kemp, 1998) in order to measure the inhibitory control of young children with ASD (mean age = 7.11 years). More specifically, both tasks required of the participants to hold an arbitrary response rule in WM and to inhibit a prepotent response. Thus, these measures are considered as measures of both WM and inhibitory control. Their results showcased that children with ASD exhibited worse performance in the Knock-Tap test than their TD counterparts, but found no significant difference in the performance of both groups as far as the Day-Night task is concerned. While both tasks measure inhibitory control as a function of WM abilities, the disparity in the results can be explained through the nature of the tasks. According to Russell (1997), children with ASD seem to have an impaired ability of using inner speech to maintain arbitrary response rules in WM and thus guide behavior, something that was measured via the Knock-Tap test. On the other hand, the unimpaired performance in the Day-

Night test can be attributed to the fact that the nature of the task does not require a subvocal rehearsal so as to maintain the task rules in WM (Russell, 1999). As a result, it can be suggested that there might be a deficit in verbal self-regulation in autism. Moreover, the researchers used the NEPSY Tower task (Korkman et al., 1998) which combines WM (maintaining verbal and/or visual representations of the correct sequence in mind) and inhibitory control (inhibiting direct placement of a disk into its final destination; Roberts & Pennington, 1996; Russell et al., 1996). The ASD participants performed worse than the TD ones, adding to the preponderance of evidence about the difficulty that individuals with ASD encounter in the Tower tasks (Bennetto et al., 1996; Hughes et al., 1994; Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994; Ozonoff et al., 2004, 1991). Therefore, there is a consistency in the findings as to the impaired inhibitory control of individuals with ASD in tasks that require a combination of maintaining information in WM while inhibiting a response.

To sum up, numerous other studies have yielded mixed results as far as inhibitory control in ASD children is concerned, primarily due to differences in the methodology of the experiments and the nature of the tasks, as well as the age of the participants, which ranged from 8 to 13 years (Christ et al., 2007, 2011)

As the present study will be examining inhibition through the Eriksen Flanker task and the Stop Signal Task, we should note here some previous research conducted on ASD individuals using the same tasks in order to see if their results advocate for an intact or an impaired inhibitory control system in ASD.

Firstly, Larson et al. (2012) used a modified Eriksen flanker task in order to measure the inhibitory control of HFA adolescents (mean age = 13 years) comparing them to TD youngsters. The participants were shown a series of five arrows in either congruent or incongruent direction and were instructed to press the correct button based on the direction of the target stimulus which was the middle arrow. Their findings showed that, even though both groups exhibited higher reaction times in the incongruent trials, the ASD group exhibited poorer performance in inhibiting a response compared to their TD counterparts.

In addition, Schmitt et al. (2018) used a Stop Signal Test in order to examine inhibitory control in ASD and TD participants (mean age = 12.3 years). The task included "GO trials" in which participants were instructed to press a button when the target appeared and "STOP trials" in which participants were instructed to inhibit button-pressing when a stop signal stimuli appeared on screen. Relative to TD controls, ASD participants showcased lower accuracy on STOP trials, suggesting a deficit in inhibitory control. These findings can be associated with failures to strategically delay a behavioral response onset that might lead to inhibitory control deficits as well as repetitive behavioral patterns that ASD individuals usually exhibit.

Lastly, Saenz et al. (2020) examined inhibitory brain dysfunctions of ASD and ADHD children (mean age = 10 years) compared to TD controls by administering a Stop Signal Test along with evidence from fMRI measurements. However, contrary to previous results, they found that ASD participants did not significantly differ from TD controls in inhibiting a response, as both groups exhibited similar reaction times to the task.

To conclude, it could be argued that once again research conducted on the assessment of inhibitory control in ASD children produced mixed results as to the existence of an impairment in this particular EF. Thus, further research needs to be done in order to elucidate the nature of inhibition in ASD children.

2.5 Language acquisition in ASD

Children diagnosed with ASD are said to face various impairments as far as language acquisition is concerned, even though delays and deficits in language are not core features of ASD (Kurita, 1985; Short & Schopler, 1988; Lord & Paul, 1997). However, language impairments constitute a very important feature for predicting the prognosis and developmental course of children with this disorder (Rutter, 1970; Ventner, Lord & Schopler, 1992). According to DSM-V, verbal and non-verbal communication impairments depend on numerous factors, such as chronological age, intellectual abilities, and treatment history. The language impairment in individuals with ASD ranges from complete absence of speech to delays in language acquisition, comprehension difficulties, or use of overly literal language. However, DSM-V clearly states that the use of language for communicative purposes is impaired in ASD even when formal linguistic skills, such as grammar and vocabulary, are intact (APA, 2013). Some early studies indicated that almost 50% of ASD individuals never fully acquire functional speech (Prizant, 1996; Rapin, 1991), whereas some more recent studies found that around 25% belong to the non-verbal ASD group (Tager- Flusberg, Paul & Lord, 2005). Apart from the possible impairments in the main domains of language, ASD individuals differ from their TD counterparts in engaging in "echolalia", which is the immediate or delayed imitation (echoing) of language (Tager-Flusberg & Calkins, 1990) and in the invention of novel words (neologisms) often with a specific idiosyncratic meaning (Eigsti et al., 2007; Rumsey, Rapoport & Sceery, 1985; Rutter, 1970; Tager-Flusberg & Calkins, 1990; Volden & Lord, 1991).

The question that arises here is whether children with ASD face an impairment or a delay in acquiring language, as language development in autism is characterized by extensive heterogeneity, since impaired or delayed language acquisition does not constitute a similar trait of all the children who belong to the spectrum. One factor playing a major role in elucidating the nature of language deficits in ASD is to examine the unfolding of these deficits over time (Eigsti & Bennnetto, 2009). Language delays are a common trait among autistic populations, even among HFA individuals with autism (i.e. those with IQs in the normal range) (Eigsti & Bennnetto, 2009). Language delays, however, are obviously correlated with verbal IQ assessments, while they seem to be more weakly correlated with non-verbal IQ (Eigsti & Bennnetto, 2009). For example, one study examining ASD toddlers aged 3;6 showed that language was more strongly associated with joint attention and imitation than non-verbal IQ (Charman, Baron-Cohen, Swettenham, Baird, Drew & Cox, 2003). On the other hand, a study by Eisenmajer et.al. (1998) showed that early language delay was related to the severity of the autistic symptomatology, along with motor skill delays, early in childhood, but not later in life.

It has long been argued that LFA individuals exhibit more salient grammatical deficiencies than HFA individuals, so much that "language impairment and intellectual disability almost always co-occur together when associated with autism" (Boucher, 2009:206). However, the role of IQ in the grammatical development of autistic individuals is still blurry. Kjelgaard & Tager-Flusberg (2001) have reported that both intellectually impaired and unimpaired children with ASD scored low on a battery of standardized tests of grammar and vocabulary comprehension.

Thus, the results that have been reported are mixed and it seems that extensive research needs to be conducted on this topic in order to shed light on the nature of the language impairment in ASD. For instance, Tager-Flusberg et al. (1990) conducted a longitudinal study in order to investigate the spontaneous speech of a group of ASD children, comparing its grammatical complexity, in terms of mean length of utterance (MLU), with a group of Down syndrome children, as well as with TD controls, all matched on non-verbal age. Their results did not show any significant differences in their development, even though the ASD group showed a delayed onset of development. Other studies, which investigated the acquisition of grammatical morphemes, suggested that the grammatical development of ASD children was mainly typical (Bartolucci, Pierce & Streiner, 1980; Howlin, 1984). On the other hand, Eigsti, Bennetto & Dadlani (2007) found that children with autism produced less syntactically complex language than their TD counterparts, matched on lexical knowledge and non-verbal IQ. As stated by Eigsti et al. (2011), the different findings might derive from methodological issues, such as the use of spontaneous speech versus structured tasks.

As far as phonological development is concerned, the reported studies seem to agree on this component being intact in children with ASD (Eigsti et al., 2011). For example, Bartak, Rutter and Cox (1975) used both structured and spontaneous speech settings and found that children with ASD had only few articulatory problems when compared to, matched on non-verbal IQ, dysphasic controls. Also, Klelgaard and Tager-Flusberg (2001) reached similar results when studying 89 HFA children, as this group scored within the normal range of an articulatory test. Nonetheless, some studies have found phonological deficits in ASD individuals. Bishop et al. (2004) assessed 80 children with ASD, aged 9-10 years, along with 59 controls by using the Nonword Memory Test and a read-aloud task, concluding that the ASD group appeared to be more impaired in phonology. The disparity in the findings concerning phonological and articulatory problems can be attributed to the different levels of severity that are found inside the spectrum. More specifically, LFA individuals with autism, as well as very young autistic children, seem to show impairments in phonology (Lord & Paul, 1997), while individuals belonging to other subgroups of the spectrum are more likely to follow a typical trajectory in phonological development (Rapin et al., 2009; Tager-Flusberg, Lord & Paul, 1997).

Various studies have been conducted as to how individuals with ASD process semantic information. Semantics is concerned with the knowledge of the meanings of words and how these meanings map onto the real world. However, the results of studies investigating semantics in ASD have proven conflictive. A great number of studies found that children with ASD have difficulty in understanding the meanings of verbs that indicate a person's internal mental state (i.e. know, think, remember, etc.) (Kazak, Collins & Lewis, 1997; Ziatas, Durkin & Pratt, 1998). Other studies have shown that ASD children are less primed by semantically-related words, though priming by pictures remains intact (Kamio, Robins, Kelley, Swainson & Fein, 2007; Kamio & Toichi, 2000). On the other hand, several researchers concluded that semantic processing, either concerning comprehension or production, is unimpaired in individuals with ASD. For example, Eigsti et al. (2007) found that ASD children produced a greater variety of different words in spontaneous speech than the mentally retarded group, which were matched on receptive vocabulary. Also, Ungerer & Sigman (1987) found that ASD children had similar abilities in sorting items into form, color, and functional categories, when compared with age-matched mentally retarded (MR) and typically developing (TD) children.

Nevertheless, pragmatic and discourse functions are widely accepted as the most socially involved aspects of language that are impaired in children with ASD, almost uniformly. Appropriate turn-taking, the choice of specific register when addressing a hearer, as well as the understanding of metaphorical, or else non-literal, meanings are some of the most conspicuous problems that children with ASD face in a communicative context. It has been suggested that ASD children often use pedantic language, or else highly-informative language, which violates Grice's (1975) conversational maxims of relevance and quantity (Ghaziuddin and Gerstein, 1996).

Furthermore, research has noted that children with ASD find it difficult to understand utterances with metaphorical, ironic, or sarcastic meaning (Adachi et al., 2004) and sometimes adopt socially inappropriate styles of communication (Volden, 2002). The impairment in high-level pragmatic and discourse functions can be attributed to two theories: the Theory of Mind approach and the Executive Functions approach. The former theory suggests that difficulties in representing the contents of other people's minds are central in our understanding and may provide a critical constraint on pragmatic language skills (Baron-Cohen, 1988). The latter theory, that of Executive Functions, suggests that there are impairments in a set of cognitive processes, involving working memory, inhibition, set shifting, planning, or goal maintenance. The aforementioned impairments seem to play a crucial role in the development of children, and thus account for failure in pragmatic and discourse tasks, as ASD children might be unable to simultaneously consider and respond to multiple sources of information (Ozonoff et al., 2004; Pennington & Ozonoff, 1996).

Before moving to the impairments of ASD children in syntax, we need to consider morphological development in this group as the results of the studies already conducted seem to be disparate. On the one hand, Bartolucci, Pierce & Streiner (1980) found that children with ASD (mean age = 10 years) more often omitted obligatory morphemes when compared to TD children matched on verbal age. These findings suggested a delayed morpheme production, rather than a generalized language delay. On the other hand, Waterhouse & Fein (1982) showed that at least the early-acquired morphological rules were similarly learnt by both ASD and TD children. Another study conducted by Howlin (1984) suggested that the order of acquisition of grammatical morphemes may be delayed, but the developmental progression itself is similar to that of TD children.

2.5.1 Grammar in ASD

As the topic of this study is the comprehension of Relative Clauses in ASD children, we should focus here on the syntactic impairments that have been reported in this population. Syntax is the domain of language that refers to the combination of words into phrases (Eigsti et al., 2011). It is considered as the most complex linguistic domain and many studies have been conducted concerning the nature of the impairment in neurodevelopmental disorders, with autism being one of them. However, the results of the studies have been disparate as to the presence of a syntactic impairment or delay in this population, as different areas of syntax were examined.

Some older studies back in the 1970s found that syntax in children with ASD is deviant in a more fundamental way (Bartolucci et al., 1980; Dalgleish, 1975). First of all, one of the most widely examined areas of syntax is the one concerning the production of past tense verb forms. For example, a study by Bartolucci & Albers (1974) showed poorer production of past-tense verb forms in the ASD group (mean age = 8,4 years), implying a more general deficit in “deictic” syntactic categories, when compared to mentally-retarded (MR) and TD children matched on mental age. For similar results concerning impairment in the past marking tense, see also Botting & Conti-Ramsden (2003) and Roberts et al. (2004).

Furthermore, Walenski et al. (2014) examined a group of ASD boys (mean age = 10,8 years) and compared them to age-matched TD controls in a task concerning regular and irregular past tense forms in English. They measured both the accuracy and the response times of the production of these inflected forms and they found that ASD participants responded much faster than the control participants in the past tenses of verbs that follow regularized patterns, while they presented lower response times in the cases of irregular verb forms or novel verbs. These results suggest that the production patterns presented are based on the dual-system models of morphology and the Procedural Deficit Hypothesis for autism, which support that there might be some abnormalities in the computation of *–ed* forms while there might be a relative sparing of the computation as far as lexically dependent, or else irregular, past verb forms are concerned.

Another area of syntax in which impairments were found is the third person singular *(-s)* and the present progressive marking *(-ing)*. To explore their nature, a grammaticality judgement task was used by Eigsti and Bennetto (2009) in order to examine if ASD children (mean age = 13 years) exhibit any grammatical differences when compared to TD children, testing a wide range of morpho-syntactic phenomena. Their results showed that ASD children had lower response sensitivity for third person singular *(-s)* and present progressive marking *(-ing)*. Also, the differences between the groups were more salient in the younger ASD participants, who scored lower overall on the grammaticality judgement tasks as they performed below the mean score than the younger TD participants. It is interesting to note here that the ASD group showed greater impact of sentence length, a finding that is consistent with the Executive Function theory for ASD (Bennetto, Pennington & Rogers, 1996), as the length of the sentences posed increased demands on working memory, making the task more difficult for the autistic population. For similar results on present progressive marking (-ing), see also Roberts et al. (2004).

Also, the comprehension of transitive and intransitive verbs was examined by Prior and Hall (1979), who concluded that ASD children (mean age = 12 years) were lacking the ability to comprehend transitive verb phrases (the cases in which the verb requires a direct object e.g. *the man drew a picture on the chalkboard*) and intransitive ones (e.g. *the man painted*), as well as the ability to use word meaning to assist in comprehension, when compared to Down syndrome and TD children.

As far as the comprehension of pronouns is concerned, Perovic, Modyanova & Wexler (2013) investigated two distinct properties of the binding module of grammar (Principle A that governs reflexives and Principle B that, together with its associated pragmatic rule, governs pronouns). The researchers divided the autistic children (mean age = 11 years) in two subgroups: the ALN group, i.e. autistic children with normal language, and the ALI group, i.e. autistic children with language impairment. They compared these two groups with participants diagnosed with William's Syndrome (WS) and TD children. They found that all four groups presented equal delays in the comprehension of personal pronouns, something that aligns with prior evidence in TD literature of these delays being attributed to delayed pragmatic abilities. Their most striking finding, however, was that the ALI group exhibited pronounced difficulties in comprehending the reflexive pronouns, and particularly the antecedent of a reflexive pronoun that must c-command it. Thus, they concluded that the impairment in Principle A is unrelated to general language delays or cognitive and pragmatic deficits. Also, the ALN group revealed intact knowledge of reflexive binding, but an ongoing difficulty with the comprehension of pronouns. Likewise, a study by Terzi, Marinis, Francis & Kotsopoulou (2014) concluded that reflexive and strong personal pronouns were equally comprehended between the ASD and the TD groups (mean age = 6.8 years), while ASD children performed less accurately than controls in the comprehension and production of clitics, rendering clitics a vulnerable grammatical domain for Greek-speaking ASD children.

Apart from the studies that have shown syntactic impairments in ASD, a few studies have supported that the syntactic skills of ASD children follow a normal trajectory as that of TD children, but are indeed delayed (Fein & Waterhouse, 1979; Howlin, 1984; Tager-Flusberg et al., 1990). We should note here that the studies supporting a language delay were conducted in young children with ASD and did not account for a bigger time span in order to examine if they delay is still present during the next stages of development.

Eigsti, Bennetto & Dadlani (2007) addressed the issue of syntactic and higher-level discourse abilities of verbal children with autism (mean age = 5 years) and compared them to TD children (mean age = 3 years) matched on non-verbal mental age, by assessing different morphosyntactic abilities through MLU and IPSyn (Index of Productive Syntax; Fowler, 1980; Scarborough, 1990; Scarborough, Rescorla, Tager-Flusberg, Fowler & Sudhalter, 1991), which is considered as a more sensitive measure of language level than MLU, mainly for children at this developmental level, as it offers a more fine-grained analysis of disparate domains of syntax (Scarborough et al., 1991). Their findings suggested syntactic delays, as the ASD participants produced less complex language than expected for their developmental level as well as shorter MLUs. More specifically, the ASD group exhibited specific delays in grammatical complexity and, in particular, developmental scatter, something that was inconsistent with simple developmental delay. Also, an impairment in discourse management was found as well as production of non-meaningful words (jargon) was more common in ASD children, implying a developmental delay in these fields and a very specific nature of the syntactic impairments in autism.

On the contrary, a few studies indicated that there is no significant syntactical impairment in ASD children. The impression that grammar is not particularly affected in autism was widespread in the traditional literature (e.g. Lord & Paul, 1997). Nonetheless, more recent studies have also supported this notion.

For example, a longitudinal study by Tager-Flusberg et.al. (1990) did not find any significant differences when having assessed the grammatical complexity of expressive spontaneous language among age-matched ASD and Down syndrome children, implying that autism does not involve a fundamental impairment in formal aspects of language. Moreover, a study conducted by Howlin (1984) examining the acquisition of grammatical morphemes suggested that its developmental trajectory was no different than that of TD children, even though it might be delayed in ASD children.

Lastly, another study by Tovar et al. (2014) assessed the production and comprehension of tense/aspect morphology in ASD children (mean age = 4 years old) compared to TD controls. They concluded that ASD children did not show any significant difficulties in the comprehension of grammatical aspect morphology, as their comprehension correlated with the production of spontaneous speech and their scores at standardized tests.

Therefore, it is evident that results concerning syntax in ASD are conflictive, as many researchers support a conspicuous impairment, while others support a normal but delayed developmental pattern or no impairment in this domain of language. These results need to be carefully considered before any conclusions are reached concerning grammar in ASD populations.

2.6 Acquisition of Relative Clauses

The acquisition of Relative Clauses is a grammatical domain that many researchers found interesting from a developmental perspective. A number of studies have been conducted in order to determine the nature of the acquisition of RCs in order to get a better insight into the different levels of their production and comprehension.

During their developmental trajectory, children seem to quickly develop their production and comprehension skills concerning RCs, as kids start *producing* them even at the age of 3. According to Varlokosta (1997), who tested 20 Greek-speaking children from 2,6 to 5,6 years, children seemed to apply wh-movement to produce subject and object RCs, with these results being in agreement with a comparative study on the production of RCs by Greek and Hebrew speaking children (Varlokosta & Armon-Lotem, 1998). However, it has been shown that children seem to master the *comprehension* of RCs between the age of 5 and 6 (Hakansoon & Hansson, 2000), a phenomenon that is intriguing since it suggests that, in the case of RCs, and especially in the case of object RCs with matched features in subject and object DPs, their comprehension seems to come at a later developmental stage than their production.

2.6.1 Acquisition of Relative Clauses in Typically Developing children

One of the most prominent features in the comprehension of RCs lies in the difference between Subject Relative Clauses (hereafter subject RCs) and Object Relative clauses (hereafter object RCs). Relative clauses are characterized by movement either from subject or from object position, as well as by co-indexation with a noun outside of the relative clause (Chomsky, 1981). For instance, in the subject RC sentence (1) below, the head of the relative clause “the queen” is co-indexed with the subject position of the embedded clause, meaning the trace of the moved element. In the object RC sentence (2), there is a movement of “the queen” from an object position.

(1) Show me the queen that is holding the women.

(2) Show me the queen that the women are holding.

More specifically, in an object RC as in (2), the fronting of the object “the queen” requires the crossover of a subject “the women”, both of which share similar grammatical features as full NPs. The parsing of the structure becomes more difficult for the computational system due to the intervening (i.e. c-commanding) lexical subject, which creates a dependency within the feature of the target. On the other hand, in the case of subject RCs as in (1), the absence of an intervener makes the parsing of this type of structure easier (Durrleman, Marinis & Franck, 2016). In order to process these sentences, what is needed is the construction of a relation between the moved element and the position from which it was moved. Therefore, the difficulty in the comprehension of the object RCs lies in locality constraints (Friedmann et al., 2009; Contemori & Marinis, 2013) as well as the greater demand that object RCs pose on working memory relative to subject RCs (Frazier and Flores D’Arcais, 1989; De Vincenzi, 1990). This evidence is corroborated by the Minimal Chain Principle (De Vincenzi, 1990), which supports that smaller chains of clauses seem to be more easily produced and understood. In particular, in subject RCs the distance between the trace and the element that is being moved is shorter than the one in object RCs. Thus, as the dependence is not close and the series of elements is non-canonical, the comprehension of object RCs adds a bigger computational burden to the parsing of these structures when compared to that of subject RCs.

The locality effects of subject and object RCs can be explained through a principle called Relativized Minimality (RM) (Rizzi, 1990; 2004). This theory supports that a local relation between the trace (X) and the moving element (Y) cannot hold if there is an intervener (Z) which shares the same structural type (number, gender) as the trace, as shown in configuration (1). When the moving element has the same grammatical features with the intervener, then the structure becomes more difficult to comprehend. On the other hand, if the grammatical features of the NPs differ, the influence of the minimal distance is lessened or even eliminated, rendering this type of structures more easily comprehensible.

(1) …X…Z…Y…

In terms of extending the RM theory, Friedmann et al. (2009) have made a distinction between the difficulty presented in the comprehension of object RCs by stating that this difficulty depends on the structural similarity between the A’-moved element and the intervening subject. When the moved element and the intervening subject were structurally dissimilar in terms of lexical NP-restriction, the participants performed better. However, when both the moved element and its trace shared the similar grammatical features and included a lexical NP-restriction, the structures became more difficult to comprehend, as the A'-dependency requires reanalysis and thus a bigger computational burden.

Before we move onto the comprehension of RCs in ASD, we should note some studies that have been conducted in TD children in order to elucidate the nature of the acquisition of this type of structures in normally developing children. Generally, it has been found that subject RCs are more easily understood than object RCs (Adani et al., 2010; Correa, 1995; de Villiers et al., 1979; Friedmann et al., 2009), with an enhanced comprehension during development (Adani, 2011; Arosio et al., 2009). Although there might be cross-linguistic differences due to the absence of this type of clauses in some languages, the findings suggest that, even cross-linguistically, subject RCs are easier for children to comprehend than object RCs (Guasti et al., 2012).

Stavrakaki (2001) examined the comprehension of RCs in 4-year-old Greek-speaking children through the use of an act out task. The results suggested that children showed a better performance on right branching object RCs (*The donkey is pushing the cow that the cat is holding*) than on right-branching subject RCs (*The donkey is pushing the cow that is holding the cat*).

However, a study conducted in Italian-speaking children yielded different results concerning not only right branching RCs but also center-embedded RCs. Adani (2009) examined the comprehension of RCs in 4-year-old Italian-speaking kids and found that children comprehend right branching subject RCs much better than right branching object RCs. These results are corroborated by other studies which concluded that Italian-speaking children comprehend center embedded subject RCs better than center-embedded object RCs (Guasti et al., 2012). Thus, it is evident that the comprehension of object RCs is favored by Greek-speaking children, while the opposite holds for subject RCs, when compared to Italian-speaking children, who display the opposite comprehension pattern. The difference that emerges between these findings might be attributed to the fact that the Greek language presents the factor of morphological case in the DPs. Nevertheless, the different results might also derive from the different methods and experimental material used in the aforementioned studies.

To further clarify these findings, Guasti, Stavrakaki & Arosio (2012) examined the comprehension of RCs in both Italian-speaking (mean age = 5,4 years) and Greek-speaking (mean age = 5,1 years) TD children in order to examine any cross-linguistic differences and how these might impact the comprehension of RCs. The team conducted two experiments. First, they wanted to reveal if morphological case on DPs in Greek plays a role in the different comprehension patterns that are evident between Greek-speaking and Italian-speaking children. To do so, they neutralized the morphological case in Greek in order to make the structure in both languages similar. The only element that distinguished a subject RC from an object one was the number agreement on the verb. An example of a subject RC was *Show me the sheep that is pulling the donkeys*, while for an object RC was *Show me the sheep that pull the donkeys*. Their results indicated that both Greek and Italian kids showcased a better performance on subject RCs than on object RCs, leading to a conclusion that the comprehension patterns of RCs do not vary between the two languages. The second experiment examined whether object RCs with unambiguous morphological case on DPs are easier to comprehend than object RCs with neutralized case and verb agreement being the only way to distinguish between subject and object structures. The examples used were *Show me the monkey that is washing the bear* for subject RCs and *Show me the monkey that the bear is washing* for object RCs. The researchers observed that there was a higher number of correct responses when the morphological case on DPs was unambiguous, rendering again subject RCs more easily comprehensible than object RCs with ambiguous case. To sum up, both experiments showed that object RCs seem to be more complex than subject RCs in Greek-speaking children.

Finally, Varlokosta et al. (2014) investigated the comprehension of non-canonical structures, including subject and object RCs, in order to examine if lexical restriction causes the minimality effects in non-canonical structures as Friedmann et al. (2009) proposed. They examined a group of 58 Greek-speaking TD children (mean age = 5,4 years) using a picture-pointing task. The structures that were chosen in the RC comprehension task included two DPs that were matched for gender (they were either both masculine or both feminine), contrary to Stavrakaki's (2001b) study. An example of a subject RC used was *Show me the doctor that is pulling the athlete* and an example of an object RC was *Show me the doctor that the athlete is pulling*. Their findings showed that children presented subject/object asymmetries across relative types, having an overall better performance in right-branching subject RCs compared to right-branching object RCs, as well as to center-embedded ones. In particular, the type of embedding affected children's comprehension of RCs, as there was a difference in the interpretation of right-branching and center-embedded RCs, with the latter being significantly more complex especially in the object condition. The pronounced difficulty of the participants in the center-embedded RCs compared to their right-branching counterparts can be attributed to sentence complexity, memory limitations, or integration costs (Bates, Devescovi & D'Amico, 1999; Corrêa, 1995; Kidd & Bavin, 2002). As proposed by Friedman et al. (2009), the asymmetry between subject and object RCs is caused due to the object being moved over an intervening subject, with both the moved element and the intervener sharing lexical NP restriction, something that renders object RCs more difficult to parse than subject RCs. Thus, Varlokosta et al's (2014) findings seem to be in agreement with Friedmann et al's (2009) predictions, even though the latter did not account for different types of RCs, meaning right-branching or center-embedded ones.

2.6.2 Acquisition of Relative Clauses in ASD children

As the topic of the present study is the comprehension of Subject and Object Relative Clauses by ASD children, we should summarize here some prior research, though scant, conducted on this topic. All of the below mentioned studies assessed the comprehension of Relative Clauses in other languages, making evidence on Greek speaking autistic children really scarce.

Durrleman, Marinis & Franck (2016) examined the comprehension of subject and object RCs in French-speaking ASD (mean age = 9.53 years) and TD children from three school levels (mean ages = 4,9; 6,8; 8,8) in order to investigate the effects of syntactic complexity in the development of A' dependencies, with complexity being examined under the light of movement, intervention, and NP-feature similarity in different developmental levels. The participants were matched on their non-verbal abilities and not on chronological age, in order to compare the performance of ASD kids to that of younger TD controls from a developmental perspective. The task consisted of *wh*-questions and RCs divided into 4 levels of complexity in a hierarchical order. Some examples of the structures under study are provided below.

Level 0: Clauses with no movement, intervention, or NP-feature similarity (Object questions in situ) (*The elephants are pushing who?*)

Level 1: Clauses with movement and without intervention or NP-feature similarity (Subject RCs and Subject questions) (*Show me the bear that is pushing the elephants. // Which bear is pushing the elephants?*)

Level 2: Clauses with movement and intervention and without NP-feature similarity (Object questions ex situ) (*Who the elephants are pushing?*)

Level 3: Clauses with movement, intervention, and NP-feature similarity (Object RCs and Object questions ex situ) (*Show me the bear that the elephants are pushing. // Which bear the elephants are pushing?*)

The results of the study showcased that ASD children had an overall lower performance than TD children in all levels of complexity, concerning movement, intervention, and NP-feature similarity. More specifically, ASD participants exhibited a lower overall performance in the most complex structures (see Level 3 above), further supporting Friedmann et al's (2009) predictions about subject/object asymmetries. The structures in Level 2 were the second most difficult for the ASD participants to comprehend, as they were also considered complex. On the other hand, the less complex structures, first those of Level 1 along with those of Level 0, seemed easier for ASD participants to comprehend as the participants made fewer mistakes. We should note here that NP-feature similarity was based on number, meaning structures in which the intervener and the moving element were matched in number (*Show me <u>the bears</u> that <u>the elephants</u> are pushing.*). Thus, the researchers found that total NP-feature similarity made the structures, and especially object RCs, more difficult to comprehend, while the participants made fewer mistakes in structures in which there was number mismatch (*Show me <u>the bear</u> that <u>the elephants</u> are pushing.*). Another important finding of this study lies in the correlation between non-verbal abilities and the scores ASD children achieved on the syntactic complexity, indicating the significance of non-verbal abilities for the development of syntactic complexity, with chronological age being a factor loosely correlated with it.

By the same token, Martins, Santos & Duarte (2018) examined the comprehension of subject and object RCs in 11 Portuguese-speaking ASD children (mean age = 9,6 years), 11 SLI children (mean age = 9 years) and 4 TD children groups (Group 1 – mean age = 3,7 years; Group 2 – mean age = 4,5 years; Group 3 – mean age = 5,11 years; Group 4 – mean age = 9,4 years). They found that ASD children found the comprehension of object RCs more difficult than that of subject RCs, with this difficulty being caused by intervention and movement, thus confirming the findings by Durrleman, Marinis & Franck (2016) above.

Ultimately, Schaeffer (2017) assessed the comprehension of object RCs in both ASD (mean age = 10,7 years) and TD (mean age = 11.5 years) children, comparing their results to adult controls. Their findings showed that ASD and TD children did not differ in their performance as far as the comprehension of these structures is concerned. However, their performance was significantly lower than that of the adults, suggesting that the comprehension of object RCs is still developing in this age spectrum.

2.7 The interface of Executive Functions and Language ability in ASD

As the present study will be examining both the nature of Executive Functions and language ability in children with autism, we should note here the relationship between these cognitive processes. The potential relation of executive deficits and language impairment, both common in neurodevelopmental disorders and more specifically in autism, has drawn the attention of many researchers (Liss et al., 2001; Russell, 1997). However, the possible links and correlations between linguistic abilities and EFs in autism have not yet been fully evaluated.

Russell and his team (Russell, 1997; Russell, Jarold & Hood, 1999) were the first ones to propose a hypothesis about a connection between executive dysfunction and language in individuals with autism. In particular, they proposed that deficits in EFs partly stem from the difficulty ASD individuals present in using internal, self-directed speech to control non-routine behaviors. Through tasks such as the Windows task (Hughes & Russell, 1993) and the Luria hand game (Luria, Pribram & Homskaya, 1964), they concluded that individuals with ASD present weaknesses in the use of verbal self-reminding so as to maintain response rules in working memory. This might eventually lead to mistakes in standard executive tasks which vie with an arbitrary and novel response rule contrary to a prepotent response tendency. Their final conclusion was that the difficulty exhibited in verbal self-regulation in ASD individuals is not directly connected to language impairment. Rather, it constitutes a deeper executive dysfunction, meaning a failure to use (internal) language in the service of self-regulation or generally exploit verbal capacities in the service of executive control.

Following Russell's hypothesis, Liss et al. (2001) also suggested that deficits in EFs are strongly mediated by language impairments common in autism, when they examined a group of ASD children through the Wisconsin Card Sorting Test (Berg, 1948). However, Liss et al.'s findings need to be considered carefully as many researchers claimed that methodological issues arose in this study (Tabachnik & Fidell, 2001).

A more recent study by Joseph, McGrath & Tager-Flusberg (2005) tried to shed light on both the nature of three EFs, working memory, inhibition, and planning, and the relationship between executive control and language abilities by comparing ASD children (mean age = 7.11 years) to TD children (mean age = 8.3 years). They assessed the performance of the participants through the use of seven different EF tasks (*working memory*: Word Span Forward and Backward; Block Span Forward and Backward; Isaacs & Vargha-Khadem, 1989); *working memory and inhibition*: Day-Night; Gerstadt, Hong & Diamond, 1994; NEPSY Knock-Tap; Korkman, Kirk & Kemp, 1998); *planning*: NEPSY Tower; Korkman et al., 1998) and two vocabulary tests (PPVT-III; Expressive Vocabulary Test-EVT). Their intriguing results showed that EF performance was not related to language ability in autism, while the exact opposite happened in TD controls. More specifically, they suggested that ASD participants did not use their language abilities in the service of executive control, as in the case of maintaining task rules in working memory or verbally encoding the sequence of moves in order to complete a task successfully. Also, in one of the tasks measuring spatial working memory, no correlation between the language abilities and the performance in the EF task was exhibited in both groups, implying that verbal mediation in such tasks is not needed and does not interfere with the participants' performance. Nevertheless, the fact that the language tests examined solely the expressive and receptive vocabulary of the participants makes the suggestions of the researchers somewhat blurry, as there is no clear evidence as to the specific language structures that ASD children might find difficult in relation to executive dysfunction. Thus, further research needs to be done in order to elucidate the exact relationship between EF and language deficits in a neurodevelopmental disorder such as autism.

Another study by Tyson et al. (2013) examined language and verbal memory in HFA individuals (mean age = 13,9 years) and compared them to individuals with optimal outcomes

(OO) and TD controls, matched on gender, age, and nonverbal IQ. They evaluated semantic and syntactical aspects of language through the Core Language Battery of the Clinical Evaluation of Language Fundamentals (CELF-IV; Semel et al., 2003). They also assessed the receptive vocabulary of the participants through PPVT, the participants' phonological memory through the Nonword Repetition subtest of the Comprehensive Test of Phonological Processes (CTOPP; Wagner et al., 1999), and the verbal learning and memory via the California Verbal Learning Test, 2nd Edition (CVLT – II; Delis et al., 2000), as well as the California Verbal Learning Test, Children's Version (CVLT-C; Delis et al., 1994) for younger participants. The researchers point out that the HFA group was a group of very high functioning individuals, thus their language deficits were not really significant, falling within the average range. Some of their findings suggested that the differences between the HFA and the TD groups in some tasks of the Core Language Battery were due to deficits in self-monitoring and attention in HFA participants. However, the performance of the HFA groups was much lower than that of the TD groups in the PPVT receptive vocabulary test as well as in the verbal memory task. It is important to note here that the researchers suggested that verbal and phonological memory contributed to the linguistic ability of the HFA participants, as they seemed to rely heavily on verbal memory abilities which are considered to play a major role in language acquisition (deAbreu et al., 2011; Gathercole, 2006).

To sum up, the aforementioned studies have tried to provide some insight into the complex relationship between EFs and language acquisition in ASD population. However, the linguistic abilities of the participants were only measured through standardized tests, rendering their findings more generalized. Thus, further research needs to be conducted in order to examine if EFs play any role in the linguistic abilities of ASD individuals concerning specific language structures.

2.8. Neural Underconnectivity in ASD

Various neuroimaging studies have been conducted to investigate the cognitive profile of people with ASD, mainly using functional Magnetic Resonance Imaging (fMRI) scans to detect the brain regions that are activated during specific tasks as well as their functional connectivity. Most of these studies support the underconnectivity theory, first developed by Just et al. (2004).

This theory supports the underfunctioning of integrative circuitry and emergent cognitive, perceptual and motor abilities, resulting in a deficit of information integration at neural-cognitive levels. Just et al. (2004) used fMRI during a sentence comprehension task and found that the degree of coordination of activation between different cortical areas in ASD participants was lower than that of controls. Similar cortical underconnectivity patterns were also found in people with ASD when performing tasks that involve social cognition (Castelli et al., 2002) and problem solving (Just et al., 2012). The purpose of studying the patterns of neurological underconnectivity in ASD has primarily been the explanation for the unrelatedness of the main symptoms of ASD, meaning social and communicative impairments as well as restricted and repetitive patterns of behavior and interests (Just et al., 2012). In particular, according to the underconnecticity hypothesis, it has been suggested that individuals with ASD might present difficulties in processing high levels of information integration and require coordination of multiple neural systems, while cognitive abilities involving local neural networks and requiring low levels of information processing seem to be intact (Williams & Minshew, 2007).

Therefore, as far as linguistic capacities are concerned, the findings seem to suggest impaired “higher order” language abilities and intact “formal “language skills in adults with ASD (Minshew, Goldstein and Siegel, 1997) and HFA children (Williams, Goldstein and Minshew, 2006). These studies include pragmatic or discourse abilities, such as comprehension and creation of story themes, metaphors, inferences and idioms, in the “higher order” linguistic abilities, while vocabulary and syntactic abilities, such as parsing a sentence structure, belong to “formal” language skills. The core difference between these two types of abilities is that higher-order ones require high levels of information integration and involve multiple neural systems, whereas low levels of information integration and local processing are needed in formal abilities (Williams & Minshew, 2007).

Those who support the underconnectivity theory believe that the components of the cognitive system correspond to cortical centers which are abnormal in ASD, as they are tuned to more autonomous and less collaborative inter-center processing. Therefore, the processing centers are loosened or underdeveloped, with the intra-center seen as the elementary circuitry and the inter-center as the integrative circuitry, with a bad connection between these two (Just et al., 2004). In the same study, it was found that, in people with ASD, there is more activation in Wernicke’s area (left latero-superior temporal) and less activation in Broca's area (left inferior frontal gyrus) which results in lower degree of information integration and synchronization across the large-scale cortical network for language processing. Generally, Broca's area is responsible for sentence comprehension, syntax, semantic processing and working memory, with the semantic and syntactic processing, as well as working memory playing a central role in the integration of the meaning of the components of a sentence. On the other hand, the left superior and middle temporal gyrus, more commonly known as Wernicke's area, is responsible for the lexical processing, while the area surrounding the posterior left superior temporal gyrus, along with the superior temporal and middle gyri, play an important role in sentence comprehension. This difference in the distribution of activation levels in Broca's and Wernicke's area result in people with ASD relying more on an enhanced word-processing ability and less on integrating processes, such as semantic and syntactic structure. Thus, there is lower functional connectivity between the pairs of Regions Of Interest (ROIs), with less synchronized activation at the time they are doing a sentence comprehension task. This lower functional connectivity can become more generalized in people with ASD as there seems to be a dissociation between intact and enhanced simple abilities and impaired higher-order abilities, like memory, language, abstract reasoning, or sensory domains.

Based on the underconnectivity theory, Koshino et al. (2005) performed an n-back working memory task with letters in HFA adults and control participants, and found that people with ASD relied more on low-level processing, as they showed good analysis of visuospatial details, perceptual learning and visual search. However, their performance was worse in language comprehension tasks, which are more complex. These findings are associated with higher activation levels in regions responsible for lower-level cognition, mainly posterior brain regions and more right hemisphere activation, specifically right hemispheric parietal regions and inferior parietal lobe, which plays the role of the information buffer of working memory. Higher activation has also been found in other posterior regions, left inferior temporal, left temporal, right temporal and left inferior extrastriate, regions that have to do with the analysis of lower level visual features. On the other hand, there was reduced activation in the left hemisphere frontal regions, with autistic people processing letter stimuli in a non-verbal fashion. What is of great importance is the fact that increased synchronization has been found between prefrontal and right parietal regions, which are the regions that are the constituents of the working memory network. Autistic people tended to shift towards the right hemisphere and posterior part of the brain in order to perform the task, with the anterior frontal components being weaker.

These findings were also supported by more recent research (Koshino et al., 2007), in which there has been found lower activation in the inferior left prefrontal area, which is responsible for verbal processing and working memory maintenance. Furthermore, in the same study, the idea of the Enhanced Perceptual Functioning was introduced, resulting in a locally oriented visual and auditory perception and enhanced lower-level discrimination, leading to visual representations used in comprehending abstract sentences.

However, it is very important to note that all the above mentioned findings are susceptible to task complexity, since not all tasks required the same complexity level, something that could have yielded different patterns of activation and thus different results.

3. The present study

3.1 Purpose of the present study

The purpose of the current study is to investigate (a) whether Greek-speaking high-functioning ASD children aged from 7 to 11 years exhibit impairments in two core EFs, WM and inhibition, (b) whether there are subject/object asymmetries in the comprehension of Relative Clauses in Greek-speaking HFA children aged from 7 to 11 years, (c) whether difficulties in the comprehension of object Relative Clauses depend on the featural specification of the moved object and the intervening subject DPs (d) whether performance on the comprehension of object Relative Clauses correlates with performance in WM and inhibition, and (e) whether the overall performance of Greek-speaking high-functioning ASD children aged from 7 to 11 years is different from the performance of age-matched TD children across all tasks.

3.2 Hypotheses of the present study

Therefore, the research questions that arise are the following.

1) Are the EFs, Working Memory and inhibition, impaired in HFA children aged 7 to 11 years?

2) Are there subject/object asymmetries in the comprehension of Relative Clauses in Greek-speaking HFA children aged from 7 to 11 years?

3) Does the featural specification of the moved object and the intervening subject DPs affect the comprehension of subject and object RCs?

4) Is there a correlation between the performance of Greek-speaking HFA children aged from 7 to 11 years in the comprehension of Relative Clauses and their performance in EF tasks?

5) Does the performance of Greek-speaking HFA children aged from 7 to 11 years differ overall from the performance of age-matched TD children across the tasks?

In order to investigate the aforementioned hypotheses, we need to conduct research and compare the results of ASD children, aged 7 to 11 years old, in all three areas examined, working memory, inhibition, comprehension of subject and object RCs, to those of TD children, matched on chronological age.

Nevertheless, the last part of the present study, the one concerning neural underconnectivity theory, will not be supported experimentally due to time and resource limitations and due to the fact that this type of research is not feasible in Greece yet.

3.3 Methodology

3.3.1 Participants

The present study includes two groups of children. The first group consists of 8 HFA children, aged 7 to 11 years old (mean age = 9.7 years), who attended public primary schools in Athens. The ASD group consists entirely of boys. All ASD participants were diagnosed with ASD by a Greek public institution for disabilities and took part in the experimental procedure with their parents' consent, who were informed about the aims of the study and the nature of the tasks.

The control group consists of 8 typically developing children, aged 7 to 11 years old (mean age = 9.68 years), who all attend public primary schools in Athens and Larissa. The control group consists of 7 girls and 1 boy. The participants took part in the experimental procedure with their parents' consent, who were informed about the aims of the study and the nature of the tasks, along with the consent of the school principals and teachers.

The demographic data of the participants can be seen in the following table (Table 3.1).

Table 3.1 Descriptive statistics – Mean and standard deviation of the two groups

		ASD children (N = 8)	TD children (N = 8)
Age	M	9,7	9,68
	Range	7,6-11,1	7,5-11,3
	SD	1,28	1,29

Note. *M* = mean, *SD* = standard deviation

3.3.2 Materials and procedure

3.3.2.1 Description of the materials

All the tasks that were used in the present study were administered through the use of a portable 14-inch screen computer.

Receptive Vocabulary: Peabody Picture Vocabulary Test (PPVT-R). In order to assess the receptive vocabulary of the participants, we used the digital version of Peabody Picture Vocabulary Test (PPVT – R), adjusted in Greek for primary school children (Simos, Sideridis, Protopapas & Mouzaki, 2006). The participants listened to a recorded word (verb, noun, adjective) and chose 1 out of the 4 images presented on the screen, the one that better matched the word they listened to. The task consists of 173 words and has a mean duration of 10-15 minutes. Also, the task does not require the use of oral or written speech, thus it is considered suitable for children who might face language or speech problems. After the participant makes a specific number of mistakes, the task ends automatically.

EF tasks

Working Memory: Verbal Working Memory: Digit Backwards Span task. The maintenance and manipulation of information in WM was measured through the use of a Digit Backwards Task. The backward condition of the digit span task (Wechsler Intelligence Scale for Children – Revised; Wechsler, 1974) has been widely used to measure the WM abilities of children ranging from 7 to 11 years (Williams et al., 2006; Williams et al., 2005b). The task consists of 8 conditions, starting from a 2-digit sequence and ending with a maximum of a 9-digit sequence. The length of each sequence of numbers increases by one digit when the participants repeat correctly 4 consecutive sequences in one condition. This task requires of the participants to listen to a sequence of numbers spoken aloud by the experimenter and repeat them in reverse order. For example, when the participants hear "7-4-3", they need to respond "3-4-7". The task ends when the participants make 4 consecutive mistakes in one condition. The scores reported represent the maximum number of digits repeated correctly.

Inhibition: Eriksen Flanker Task. In order to measure the inhibitory control of the participants, we used two tasks. The first task was the Eriksen Flanker Task (Eriksen & Eriksen, 1974) which assesses the response inhibition through information processing and selective attention, as used by Larson et al. (2012) who also examined the same population. The task consists of 10 practice trials prior to beginning the experimental task so as to ensure adequate task understanding. In the practice trials, a single arrow is presented on a 14-inch computer screen approximately 20 inches from the participants' head. The participants were instructed to press as quickly as possible the "Z" button on the keyboard when the arrow pointed to the left, while press the "?" button when the arrow pointed to the right. In the 50 experimental trials, the participants were exhibited with 5 arrows located in a box in a white background. Each trial consists of either congruent (→ → → → →) or incongruent (→ → ← → →) arrow stimuli. The participants were instructed to focus on the direction of the middle arrow, while ignoring the rest of the arrows, by pushing as quickly as possible the "Z" button on the keyboard when the middle arrow pointed to the left, while press the "?" button when the middle arrow pointed to the right. At the end of the experimental trials, the reaction times as well as the accuracy of the answers were immediately saved in the computer.

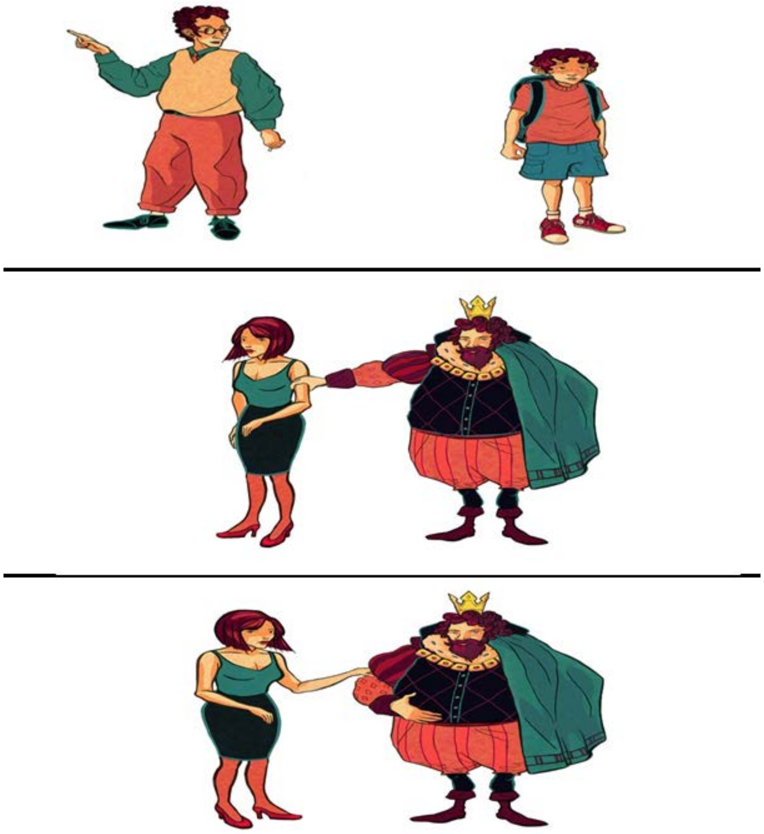
Inhibition: Stop Signal Task: The second task that was used to measure response inhibition was the Stop Signal Task (SST; Logan & Cowan, 1984), similar to Schmitt et al. (2018), who used it to measure response inhibition in ASD population. The task consists of 10 practice trials so as to ensure the participants' understanding of the task. In the practice trials, the participants were presented with a single arrow in the middle of the screen. They were instructed to focus on the color and the direction of the arrow. They had to press as quickly as possible the "Z" button when the arrow was green and pointed to the left and the "?" button when the arrow was green and pointed to the right. However, when the arrow changed from green to red, the participants had to inhibit their response and press none of the buttons. In the 50 experimental trials that followed, the participants had to follow the exact same procedure as in the practice ones. In the end of the experimental trials, the reaction times of the participants as well as the accuracy of their answers were automatically saved in the computer.

Comprehension of subject and object Relative Clauses task

In order to investigate the comprehension of subject and object RCs, we used a picture-pointing task, as used in other studies examining the acquisition of similar structures (Durrleman, Marinis & Franck, 2016; Varlokosta et al., 2014; Guasti, Stavrakaki & Arosio, 2012). The participants were asked to point on the screen the picture that matches the clause uttered by the experimenter in a neutral intonation in order to avoid any effects. Also, the experimenter asked of the participants to be fully concentrated during the task as there could be no repetition of the clauses. Before the beginning of the task, there were 4 practice trials in order for the participants to fully understand the nature of the task. The total number of pictures was 70 (10 pictures for each of the 7 conditions examined). The stimuli consisted of 3 animated pictures (see picture 1 below). Two of the pictures represented the same characters as in the sentence uttered by the experimenter, while the third one was used as a distractor, as it exhibited entirely different characters from the ones heard in the sentence. The sentences were divided into 7 conditions and 3 levels of complexity, similar to the study by Durrleman, Marinis & Franck (2016), who divided the stimuli into 5 levels of complexity. The main distinction was among active clauses, which were used as fillers, subject RCs with and without NP-feature similarity (gender and number), and object RCs with and without NP-feature similarity (gender and number). There was an equal number of sentences in all seven types of conditions (number of clauses in each condition = 10), with the task consisting of a total of 70 clauses. All types of RCs were right-branching with canonical structure for subject RCs and non-canonical for object RCs (Arfani, Doctoral Dissertation, in progress). An analysis of the clauses presented to the participants can be found in the following table listed in a hierarchical order of complexity (Table 3.2), as well as an illustration of the picture stimuli that accompanied the utterance of the clauses (Picture 3.1).

Table 3.2. The seven different conditions in the RC comprehension task

Conditions	Example
Condition 1 Active clauses	The man is touching the king. O andras akumpa ton vasilia.
Condition 2 Subject RCs, NP-similarity	Show me the king that is touching the man. δikse mu ton vasilia pu piani ton andra.
Condition 3 Subject RCs, number mismatch	Show me the king that is touching the men. δikse mu ton vasilia pu piani tus andres.
Condition 4 Subject RCs, gender mismatch	Show me the woman that is touching the boy. δikse mu tin γineka pu piani ton nearo.
Condition 5 Object RCs, NP-similarity	Show me the king that the man is touching. δikse mu ton vasilia pu piani o andras.
Condition 6 Object RCs, number mismatch	Show me the king that the men are touching. δikse mu ton vasilia pu pianun i andres.
Condition 7 Object RCS, gender mismatch	Show me the woman that the boy is touching. δikse mu tin γineka pu piani o nearos.



Picture 3.1 Experimental example of the picture-pointing task for the comprehension of subject and object RCs

(clause: Show me the woman that is touching the king.)

(δikse mu ti γineka pu piani ton andra.)

3.3.2.2 Description of the experimental procedure

The data collection began in the beginning of the school year and lasted approximately two months, from September to November 2020. Before the beginning of the data collection, the parents of the participants were informed about the nature and the duration of the tasks and gave their written consent for the participation of their children in the experimental procedure. Also, the principals and teachers of the primary schools the participants attend were informed and gave their consent to conduct the research in the premises of the school.

The data was collected from children attending different Primary Schools in Greece. More specifically, three of the TD participants attend the 12th Primary School of Athens. One TD participant attends the 105th Primary School of Athens. One of the TD participants attends the 6th Primary School of Gerakas, Athens. One TD participant attends the 12th Primary School of Halandri, Athens. Two of the TD participants attend the 6th Primary School of Larissa.

As far as ASD participants are concerned, one of them attends the 62nd Primary School of Athens. The rest of the ASD participants took part in the procedure during their attendance at a center focused on children with developmental and learning disabilities. The principal of the center gave her consent in order to conduct the experiments in the premises of the center during the sessions the children attend with their special educators, who also agreed on the administration of the experiments. Thus, the ASD participants took part in the procedure during afternoon hours.

The experimental procedure for TD children was conducted during the school day in the premises of the Primary Schools the participants attend and took place in a quiet classroom of the school in order for the participants to be fully concentrated during the process. The timetable for each participant differed according to the consent the parents and teachers gave based on the participants' school schedule.

On the other hand, the ASD participants took part in the experimental procedure in a quiet classroom in the premises of the center they attend. Again, the timetable for each participant was decided upon with the agreement of the parents and the special educators of the center.

The participants completed the first session of the task on a separate day from the second session. The tasks did not take place on consecutive days, as we tried to conduct them with a difference of at least two days in order to avoid any effect on our results.

Before the beginning of the administration of the tasks, the experimenter spent some time (5' – 10') as an ice-breaker in order for the children to feel comfortable with the experimenter. The experimenter discussed with the participants about their everyday activities, their interests, and their school life. The tasks were divided into two groups in order not to exceed an upper limit of 45' per session. More specifically, the first session consisted of the Digit Backward Task (mean duration = 10 minutes) and the comprehension of Relative Clauses task (mean duration = 25 minutes). The second session consisted of the PPVT-R test (mean duration = 15 minutes) and the two inhibition tasks, the Stop Signal Test and the Eriksen Flanker Task (mean duration = 20). The duration of each task was differentiated based on the participants' understanding of the procedure and performance in the tasks.

The tasks were administered in a randomized order for each group of participants in order to avoid any methodological effects on our results. In particular, half of the ASD and TD participants took part in the first session on the first day and the second session on the second day, while the other halves took part in them in the reverse order.

The experimental procedure did not exceed the upper time limit of 45' and no difficulties were faced during the administration of the tasks. All participants were willing to listen carefully to the instructions of the experimenter and did not quit any of the tasks before their completion. No participants were excluded from the procedure, as they were all able to complete the tasks successfully.

4. Scoring and data analysis

Descriptive statistics were conducted per condition of each task in order to explore the data. These were followed by a one-way ANOVA with age as the between factor and task condition as the within factor so as to investigate any between group differences and address the research questions. To investigate whether syntactic complexity in children ASD and TD children develops as a function of age, EFs, or receptive vocabulary, Pearson correlations between the tasks and their conditions were conducted. This way, we were able to address the hypotheses of the study. The first set of analyses compared the overall performance of the two groups across all tasks. The second set of analyses addressed which differences between the groups were statistically significant in order to clarify the differences in performance exhibited by the two groups under study. The third set of analyses examined the correlations between age and the total conditions of each task in order to investigate if EFs play any role in linguistic development of both ASD and TD children.

5. Results

In the following table (Table 5.1), the descriptive statistics for accuracy are presented, showing the mean and the standard deviation in both groups across all tasks and conditions.

Table 5.1 Descriptive statistics - Mean accuracy and standard deviation in all tasks

Task		N	Mean	SD
PPVT	ASD	8	120.7500	11.94930
	TD	8	127.6250	10.91444
	Total	16	124.1875	11.61160
Digit Backwards task	ASD	8	8.7500	3.05894
	TD	8	12.7500	3.19598
	Total	16	10.7500	3.66060
Stop Signal Task				
Arrows Correct	ASD	8	64.2500	5.99404
	TD	8	67.5000	5.42481
	Total	16	65.8750	5.77206
Arrows Wrong	ASD	8	19.0000	3.20713
	TD	8	13.7500	5.99404
	Total	16	16.3750	5.37742
Arrows No Response	ASD	8	16.7500	5.11999
	TD	8	18.7500	7.77817
	Total	16	17.7500	6.44464
Arrows Correct RT	ASD	8	559.9000	105.71282
	TD	8	594.8500	106.31683
	Total	16	577.3750	103.99849
Arrows Wrong RT	ASD	8	453.4100	111.09362
	TD	8	510.6663	108.65219
	Total	16	482.0381	110.19460

Eriksen Flanker Task				
Flanker Correct	ASD	8	88.5000	11.89237
	TD	8	97.7500	2.25198
	Total	16	93.1250	9.54900
Flanker Wrong	ASD	8	2.7500	3.01188
	TD	8	1.0000	1.51186
	Total	16	1.8750	2.47319
Flanker No Response	ASD	8	8.7500	9.55809
	TD	8	1.2500	1.48805
	Total	16	5.0000	7.65942
Congruent Accurate	ASD	8	96.0000	4.27618
	TD	8	98.2500	1.66905
	Total	16	97.1250	3.34415
Incongruent Accurate	ASD	8	92.2500	7.59229
	TD	8	98.2500	1.98206
	Total	16	95.2500	6.19139
Congruent RT	ASD	8	976.9825	267.66375
	TD	8	902.4350	188.03219
	Total	16	939.7088	226.74938
Incongruent RT	ASD	8	992.1988	276.51120
	TD	8	920.6987	185.91177
	Total	16	956.4488	230.59350
Interference Effect	ASD	8	15.2163	16.20364
	TD	8	18.2638	21.16267
	Total	16	16.7400	18.27578

RC comprehension task				
Active	ASD	8	98.7500	3.53553
	TD	8	100.0000	.00000
	Total	16	99.3750	2.50000
Subject RCs with NP-similarity	ASD	8	97.5000	4.62910
	TD	8	100.0000	.00000
	Total	16	98.7500	3.41565
Subject RCs – number mismatch	ASD	8	97.5000	4.62910
	TD	8	100.0000	.00000
	Total	16	98.7500	3.41565
Subject RCs – gender mismatch	ASD	8	98.7500	3.53553
	TD	8	98.7500	3.53553
	Total	16	98.7500	3.41565
Object RCs with NP-similarity	ASD	8	85.0000	17.72811
	TD	8	86.2500	17.67767
	Total	16	85.6250	17.11481
Object RCs – number mismatch	ASD	8	90.0000	10.69045
	TD	8	97.5000	4.62910
	Total	16	93.7500	8.85061
Object RCs – gender mismatch	ASD	8	81.2500	18.85092
	TD	8	91.2500	11.25992
	Total	16	86.2500	15.86401
RC Total Accuracy	ASD	8	93.1750	5.95789
	TD	8	96.2125	4.58146
	Total	16	94.6938	5.36848

In order to investigate any between group differences across the tasks, we conducted a one-way ANOVA. The one-way ANOVA that was conducted showed that a statistically significant difference is evident in the Digit Backward task [F (1,14) = 6,54, p = 0,023], indicating that ASD children performed worse in the Digit Span Backward task relative to their TD counterparts. Also, in the Stop Signal task, a statistically significant difference was found in the condition of wrong responses [F (1,14) = 4,77, p = 0,046], showcasing that ASD participants found it more difficult to inhibit a prepotent response than TD participants did. Moreover, in the Eriksen Flanker task, the difference between the performance of the two groups was found statistically significant in the Flanker correct condition [F (1,14) = 4,67, p = 0,048], supporting that ASD children had a difficulty in inhibiting a response compared to TD controls. Moreover, the difference between the groups in the Flanker No Response condition was found statistically significant [F (1,14) = 4,81, p = 0,046], showing that some ASD children did not respond to the stimuli presented, thus rendering their inhibitory control weaker than that of TD children. The aforementioned difficulty in this task can be attributed to errors the ASD participants made in the incongruent trials of the task, which was also found statistically significant [F (1,14) = 4,67, p = 0,048], meaning that ASD participants found it more difficult to respond to incongruent stimuli than TD controls did, without Reaction Time (RT) playing any role, as no statistically significant differences were found in RTs. In the RC comprehension task, both groups exhibited similar performances, while the condition of object RCs that include number mismatch appeared to be more difficult for ASD children with a marginally significant difference [F (1,14) = 3,32, p = 0,090], showcasing that ASD participants found these structures more difficult to comprehend than their TD counterparts, with this difference indicating that ASD children cannot use number mismatch as their TD peers do in order to overcome minimality effects. In the rest of the conditions, no other statistically significant differences were found.

Also, Pearson r correlations were conducted in order to investigate which tasks, along with which condition of each task, correlate with each other. Table 5.2 and Table 5.3 below show only the statistically significant correlations that were found in the analysis and that will be further discussed in the discussion of the current thesis (chapter 6).

Table 5.2 Correlations between tasks in the TD group

	PPVT	Arrows Wrong	Digit Span Backwards	Object RCs with number mismatch	Object RCs with gender mismatch
Age	.70	-.81*			
PPVT			.82*		
RC total accuracy				.94**	.82*

Note. *Correlation is significant at the 0,005 level (2-tailed)

** Correlation is significant at the 0,001 level (2-tailed)

Table 5.3 Correlations between tasks in the ASD group

	Flanker No Response	Interference effect	Arrows Wrong	Object RCs with gender mismatch	RC Total Accuracy
Age	-.70	-.77*			
Digit Backwards Task			-.81*	.85**	.76*
Object RCs with NP-feature similarity				.79*	
Object RCs with gender mismatch					.85**

Note. *Correlation is significant at the 0,005 level (2-tailed)

** Correlation is significant at the 0,001 level (2-tailed)

Based on the data above and starting from the control group, the age of TD children was marginally correlated with the scores in the receptive vocabulary test (PPVT-R) [r(16) = 0,70, p =0,051], meaning that the older the children, the better the performance was in this task. Also, age was inversely correlated with the wrong answers in the Stop Signal task [r(16) = -0,81, p = 0,015] which means that the older the participants, the fewer the mistakes they made in this condition of the task. Another statistically significant correlation was found between the scores in the Digit Backward task and the ones in PPVT-R [r(16) = 0,82, p = 0,013], which shows that the performance in the WM task was highly correlated with the performance in the receptive vocabulary one. Moreover, in the RC comprehension task, not many correlations were found, as most TD participants scored really high in this task. However, there was a statistically significant correlation between the condition of object RCs with NP-similarity and the condition of object RCs with number mismatch [r(16) = 0.94, p = 0,001]. Furthermore, the condition of object RCs with number mismatch was highly correlated with the total accuracy in the RC comprehension task (p = 0,001). Lastly, the condition of object RCs with gender mismatch was also correlated with the total accuracy in the RC comprehension task [r(16) = 0.82, p = 0,013].

Moving on to the correlations found in the ASD group, age was inversely correlated, though marginally, with the No Response conditions in the Eriksen Flanker task [r(16) = -0,70, p = 0,052], showing that as ASD children grow up, it is less likely that they will not respond to the stimuli presented. Age was also inversely correlated with the interference effect between the congruent and incongruent trials of the Eriksen Flanker task [r(16) = -0,77, p = 0,025], which showcases that the younger the ASD participants were, the more conspicuous the difference was between the congruent and the incongruent trials of the task. The performance of ASD participants in the Digit Backwards task was found to be inversely correlated with the Wrong condition in the Stop Signal task [r(16) = -0,81, p = 0,014], meaning that the better the performance in the WM task, the fewer mistakes the participants made in the inhibition task. Moreover, the performance in the Digit Backwards task was highly significantly correlated with the condition of object RCs with gender mismatch [r(16) = 0,85, p = 0,008] and the total accuracy in the RC comprehension task [r(16) = 0,76, p = 0,003), displaying that the lower WM capacity is, the more difficult it is for ASD children to comprehend object RCs with gender mismatch. Lastly, an internal correlation was found between two conditions of the RC comprehension task: the condition of object RCs with NP-similarity and object RCs with gender mismatch [r(16) = 0,79, p = 0,019]. Similarly, a statistically significant correlation was yielded between the condition of object RCs with gender mismatch and the total accuracy in the RC comprehension task [r(16) = 0,85, p = 0,008].

6. Discussion – Limitations – Future research

6.1 Discussion

The present study tried to investigate three major parts of cognition: two EFs, WM and inhibition, and the acquisition of relative clauses, as well as the interaction between them, under the light of autism, a neurodevelopmental disorder, and typical development. In order to test our hypotheses, we administered a series of tasks measuring the receptive vocabulary of the participants (PPVT-R; Simos, Sideridis, Protopapas & Mouzaki, 2006), WM (Digit Backwards task from the WISC-revised; Wechsler, 1974), inhibition (Eriksen Flanker task; Eriksen & Eriksen, 1974; Stop Signal task; SST; Logan & Cowan, 1984), and the ability to comprehend RCs (RB comprehension; Arfani, Doctoral Dissertation, in progress).

The sample of the present study consisted of 8 Greek-speaking HFA children and 8 Greek-speaking TD children, all of whom completed the experimental procedure successfully. The data collection process lasted two months and was held in the beginning of the school year. In sum, the participants completed 2 experimental sessions, in which the 5 tasks administered were divided so as not to exceed an upper limit of 45’ per session. After the completion of the data collection process, a statistical analysis of the data was conducted in order to yield our results.

Our first research question was whether ASD children exhibit impairments in two major EFs, WM and inhibition. As far as WM is concerned, our results indicated that ASD participants showed a poorer performance in the Digit Span Backwards task compared to their TD counterparts. This aligns with the results of previous studies, which supported a WM deficit in ASD children of similar age when administering the same task (Schaeffer et al., 2018), as well as with results of previous studies examining samples of older ASD children (Schuh & Eigsti, 2012).

Moving to inhibition, our results showed that ASD children had an overall lower performance in both inhibition tasks compared to their TD counterparts. More specifically, ASD children performed more poorly in the Stop Signal Task, in which they were required to inhibit a prepotent response. However, we should note here that this poor performance was not attributed to high reaction times, as the RTs of both groups did not differ significantly. Thus, it could be argued that the impairment of ASD population in inhibition is attributed to other factors, such as chronological age or WM, two factors with which inhibition capacity was correlated. Our results are in agreement with those of Schmitt et al. (2018), who also administered the same task and reported lower accuracy in the STOP trials of the task, suggesting an impairment in the inhibitory control of the ASD participants. Furthermore, ASD participants performed worse in the second inhibition task, the Eriksen Flanker task, than the TD controls. More specifically, ASD participants completed fewer correct trials, along with more trials in which they did not give a response, relative to TD participants. The mistakes the ASD participants made in this task were more conspicuous in the incongruent trials, in which the stimuli presented were more complex for the computational system, implying a deeper impairment in inhibition, as no statistically significant difference was found in the RTs of both groups. This finding is consistent with the findings of Larson et al. (2012), who also used the same task to assess the inhibitory control of ASD children, showcasing a deficit in inhibition.

In the current study, we also investigated the comprehension of subject and object RCs in Greek-speaking HFA and TD children. Our second research question tried to answer if there are any subject/object asymmetries in the comprehension of RCs. Our results showed that both groups performed almost equally well in this task, without any statistically significant differences having been drawn from our statistical analysis. However, the data indicated that ASD participants found object RCs with number mismatch more difficult to comprehend than the TD controls, even though this difference was marginally significant. This finding slightly aligns with previous findings for children with ASD (Durrleman, Marinis & Franck, 2016). The high complexity of object structures is proved by the Relativized Minimality Theory, which means that when the intervening (i.e. c-commanding) lexical subject creates a dependency within the feature of the target, these structures become more difficult to parse. However, this is not the case in subject RCs, in which the absence of an intervener makes them easier to comprehend. Similarly, our data did not indicate any difficulties in the comprehension of subject RCs, while a small difficulty in comprehending object RCs was evident, implying that there is an underlying asymmetry between subject and object RCs, attributed mainly to locality constraints.

Our third hypothesis was whether difficulties in the comprehension of object RCs depend on the featural specification of the moved object and the intervening subject DPs. Our results indicated that ASD participants found object RCs with number mismatch difficult to comprehend, while TD participants did not face any problems in the comprehension of this type of clauses. This finding is also in agreement with previous findings by Durrleman, Marinis & Franck (2016), who also concluded that when the intervener and the moving element differ in number, object RCs are rendered more difficult to comprehend by ASD children, insinuating that ASD children are not able to use number mismatch in order to override minimality effects. However, as far as TD children are concerned, no difficulties were encountered in the RC comprehension task, leading to the conclusion that by this age, TD children seem to have acquired the comprehension of subject and object RCs, with no subject/object asymmetry being evident.

Our fourth research question was whether the performance in the RC comprehension task correlates with the performance of the participants in the three EF tasks administered. As far as TD children are concerned, no statistically significant correlations were found between the aforementioned tasks, as TD children performed really well in the whole battery of tasks administered. In the ASD group, only few correlations were found between the tasks measuring EFs and the RC comprehension task. More specifically, the performance in the WM task was highly correlated with the total accuracy in the RC comprehension task as well as with the condition of object RCs with gender mismatch. This leads us to the conclusion that WM might play a role in the comprehension of RCs in ASD population, implying that, when ASD children exhibit good WM capacity, they find it easier to parse and comprehend more complex structures, such as object RCs. Nevertheless, more correlations were found between both the age of the participants and some specific conditions of the tasks, as well as between tasks. However, these correlations do not form part of the present hypothesis and this is why they are being discussed under the light of future research (see 6.3. Future research, below).

To conclude, it is essential to mention that this is the first time RC comprehension is studied in Greek-speaking HFA population, as previous studies examined this type of structures in other languages (for French see Durrleman, Marinis & Franck, 2016; for Portuguese see Martins, Santos & Duarte, 2018) or in TD population (Varlokosta et al., 2014; Guasti et al., 2012; Adani et al., 2010). Not to mention, this is the first time that RC comprehension is being discussed in relation to EFs in ASD population, since EFs are considered to play a major role in linguistic aptitude.

6.2 Limitations

The findings of the current study should be carefully examined under the light of some limitations. The first fundamental limitation is the number of the participants, which was relatively small, in order for safe conclusions to be reached as to the topics examined. Also, the age spectrum we examined was very specific, making our results applicable only in these ages without taking into account the developmental trajectory of the participants. Additionally, we administered only one task in order to assess the WM of the participants, something that does not definitely lead to robust conclusions. Furthermore, we also examined one aspect of WM, verbal WM, which does not offer a complete picture of the WM system in ASD populations.

6.3 Future research

All the aforementioned points that constitute the limitations of the current study could help future researchers examine these areas more thoroughly. More specifically, a bigger sample of children is proposed so as to investigate the topics in a broader perspective or in different developmental levels. Furthermore, a bigger battery of tasks assessing mainly WM could be used in order to have a more complete depiction of the nature of WM in ASD children.

It is vital to note here that the current study discussed the correlations that were found only between the RC comprehension task and the EF tasks, as this was the research question that was attempted to be answered. However, some more correlations proved to be statistically significant and this is the reason why we summarize them here so as for future researchers to try to examine them more meticulously.

First of all, as far as TD children are concerned, there was a correlation between the receptive vocabulary test (PPVT-R) and the Digit Backwards Span task, showing that the better the WM of the children, the better the performance in the receptive vocabulary test. This might lead to additional research that can examine whether WM plays any role in other linguistic areas other than the receptive vocabulary. The performance in the PPVT-R was also correlated with the age of the participants, something that was expected, as the older the children, the better their receptive vocabulary was. Moreover, age was inversely correlated with the number of wrong answers given in the Stop Signal task, meaning that the older the children, the better their inhibitory capacity becomes. This could be further examined in a younger group of children in order to investigate the age at which children seem to have a full capacity in inhibiting prepotent responses.

Concerning ASD participants, age was inversely correlated with both the condition of no response in the Eriksen Flanker task, as well as with the interference effect of the same task. This means that when participants are older, they tend to give more accurate responses rather than provide no response. Also, the interference effect between the congruent and incongruent trials of the task is lessened as ASD children grow up, implying that their inhibitory control ameliorates through their development. These findings could act as a motivation for future researchers to examine the nature of inhibition in younger ASD children so as to examine the exact nature of inhibitory control and the developmental stage at which this EF is mastered by ASD children. Moreover, the performance of ASD participants in the Digit Backwards Span task was inversely correlated with the number of wrong answers given in the Stop Signal Task, implying that the better WM capacity is, the better the performance in the inhibition task is. Thus, this means that WM and inhibition are positively correlated and both follow a similar trajectory during development. This finding could be the basis of investigating the relationship between inhibition and WM in younger, or even older, ASD populations so as to see if a correlation between them indeed exists.

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