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Sémantique lexicale et profils langagiers d'enfants avec autisme de langue hébraïque

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Résumé

La communication en général, et les capacités linguistiques en particulier, constituent de formidables obstacles pour beaucoup d'enfants avec TSA, qui ont du mal à faire connaître leurs idées, sentiments et intentions à autrui. La sémantique lexicale est fondamentale dans le choix des bons mots et la compréhension du monde autour de soi. Dans la recherche sur le Trouble du spectre de l'autisme (TSA), les capacités langagières sont communément mesurées sur la base de la performance sur des tâches qui mesurent les capacités en sémantique lexicale—les connaissances sur la signification des mots. Or, les connaissances scientifiques sur comment les capacités sémantiques lexicales sont liées aux autres aspects du langage dans le TSA sont pauvres.

Partant du Modèle d'accès lexical et du Modèle de lecture à double voie, l'étude présente a exploré la sémantique lexicale et ses liens avec d'autres capacités linguistiques chez les enfants avec TSA, avec le but de déterminer si (et avec quelle fréquence) le lexique sémantique est déficitaire, si le caractère explicite de la modalité de la tâche affecte la performance sur les tâches semantiques et enfin si le trouble sémantique affecte la performance syntaxique.

Trente-huit enfants avec TSA de langue hébraïque ont passé 16 tâches expérimentales différentes choisies pour tester les différentes composantes des deux modèles (incluant donc des tâches de compréhension et de production du langage oral aussi bien que des tâches de lecture). Pour chaque tâche, la performance globale (pourcentage d'items corrects) a été calculée et une analyse approfondie des erreurs a été conduite. La performance des participants avec TSA a été comparée pour chaque tâche à celle de participants contrôles à développement typique du même âge chronologique. Pour chaque individu avec TSA, un profil linguistique a été élaboré sur la base des points forts et des faiblesses observés dans les différentes tâches.

Trois principaux profils sémantique lexicale-langage ont été observés. Un petit nombre de participants ont eu des performances normales en sémantique lexicale aussi bien que dans toutes les autres composantes du Modèle d'accès lexical (5/38). Un nombre important des participants (14/38) ont manifesté un trouble dans le lexique sémantique ou dans son accès; tous ces participants avaient également un trouble syntaxique, qui pour certains faisait partie d'un déficit cognitif plus large. Enfin, la moitié des participants (19/38) n'avait pas de trouble de la semantique lexicale, mais ont manifesté un trouble de la syntaxe (et, pour quelqu'uns, aussi dans d'autres composantes). Deux constats importants se dégagent de ces profils. Aucun participant n'avait un trouble exclusif à la sémantique. Bien qu'une grande majorité des participants de cette étude a manfesité un trouble affectant la syntaxe, seuls certains de ces enfants avaient par ailleurs un déficit sémantique.

Il apparaît que, dans le TSA, un trouble syntaxique peut être dissocié d'un trouble de sémantique lexicale, alors qu'un trouble sémantique est toujours associé à un trouble syntaxique. Ce résultat questionne la légitimité de l'utilisation large de la sémantique lexicale comme signe de capacités linguistiques globales intactes chez les enfants avec TSA et suggère que les profils sémantique lexicale-langagiers varient dans le TSA, comme dans d’autres contextes de pathologie du langage.

Mots clé : TSA, langage, sémantique lexicale, syntaxe

Abstract

Communications in general and linguistic abilities in particular, constitute formidable obstacles for many children with ASD, who struggle with making their ideas, feelings and intentions known to others. Lexical semantics is fundamental to choosing the right words, and understanding the surrounding world. In research on ASD, language abilities are very widely measured on the basis of performance on tasks testing lexical semantic abilities—knowledge of the meaning of words. However, very little is known about how lexical semantic abilities are related to other aspects of language in ASD.

Using the Lexical retrieval model and the Dual route to reading model this study investigated lexical semantics and its relation to other abilities in children with ASD, seeking to determine whether (and how widely) the semantic lexicon is impaired, whether task modality explicitness affects performance on semantic tasks and, finally, whether semantic impairment affects syntactic performance.

Thirty-eight Hebrew-speaking children with ASD were administered sixteen different experimental tasks aimed at testing the different components of the two models (including oral language comprehension and production as well as reading tasks). For each task, overall performance (% accuracy) was calculated and an in-depth error analysis was conducted. Performance of the participants with ASD on each task was compared to the performance of typically developing chronological age controls. For each individual with ASD, a linguistic profile was created based on strengths and weaknesses observed in the different tasks.

Three broad lexical semantics-language profiles were observed among the participants with ASD. A small number showed normal performance in lexical semantics as well as all other components of the lexical retrieval model (5/38). A sizeable number (14/38) of the participants were found to have impairment in the semantic lexicon or in accessing it; all of these also had an accompanying syntactic impairment, which for some was part of a wider

cognitive deficit. And finally, half of the participants (19/38) showed no lexical semantic impairment, but displayed impairment in syntax (and for some, in other components as well). Two important results emerge from these three profiles. No participant was found to have an exclusive semantic impairment. Although the vast majority of the participants in this study were found to have some type of deficit affecting syntax, only some of these children were also found to have a semantic deficit.

It appears that, in ASD, impaired syntax can be dissociated from a semantic impairment, while a semantic impairment is always associated with a syntactic impairment. These results question the legitimacy of the wide use of lexical semantics as an indicator of intact global linguistic abilities in children with ASD, and suggest that lexical semantics-language profiles vary in ASD, as in other contexts of language pathology.

Key words: ASD, language, lexical semantics, syntax

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Introduction

Introduction (French)

Nous savons aujourd'hui que le Trouble du spectre autistique (TSA) est une trouble neurologique organique; or, son étiologie précise n'est pas encore claire. Les enfants avec TSA manifestent une grande variété de déficits affectant leur vie quotidienne. La variabilité entre les individus avec TSA est très importante et la recherche à ce jour a eu beaucoup de difficulté à tirer des conclusions sur le langage dans ce trouble, ce qui résulte en un manque critique d'outils et de méthodes diagnostics et de programmes d'intervention qui ciblent les capacités linguistiques.

Dans beaucoup d'études sur le TSA, les capacités sémantiques lexicales (mesurées en général par une tâche de dénomination d'images) sont utilisées comme indication de la compétence linguistique. Or, la recherche existante sur les capacités en sémantique lexicale dans cette population a engendré des résultats contradictoires et les conclusions sont difficiles à tirer à cause du fait que les participants dans ces études avaient des caractéristiques différentes (e.g., QI) et des tâches différences ont été utilisées à travers ces études (dénomination d'images, amorçage sémantique, appariement mot-image, parmi beaucoup d'autres). Dans Sukenik, 2012, il a été trouvé que la plupart des participants avec TSA produisait des erreurs de sémantique lexicale d'un type ou d'un autre, sur plusieurs tâches linguistiques. Une question laissée sans réponse dans cette étude était si ce résultat était particulier à ce groupe d'enfants ($N = 18$) ou aux tâches particulières utilisées (seulement deux tâches ciblant la sémantique lexicale), ou si la sémantique lexicale est très largement (ou systématiquement) affectée chez les enfants avec TSA.

Pour évaluer les capacités sémantiques et les différencier des capacités linguistiques liées, deux modèles ont été utilisés qui ont reçu un soutien empirique très large à travers des études sur des enfants avec aphasie, des enfants avec dyslexie et des enfants à développement

typique (DT). Le Modèle d'accès lexical (qui décrit comment nous partons d'un stimulus consistant d'une image ou d'un objet pour prononcer un mot à haute voix) et le Modèle de lecture à double voie (qui décrit comme nous partons d'un mot écrit pour arriver à le prononcer à haute voix). Ces deux modèles ont été choisis parce qu'ils ont des composantes partagées et nous permettraient de distinguer entre des composantes sur la base de la performance sur les tâches différentes en partant de l'hypothèse que ces tâches nous permettraient de pointer la localisation d'un déficit linguistique (s'il existe) chez des enfants avec TSA.

Utilisant le Modèle d'accès lexical et le Modèle de lecture à double voie, cette étude a exploré la sémantique lexicale et ses relations avec d'autres capacités chez les enfants avec TSA avec l'objectif de déterminer si (et avec quelle fréquence) le lexique sémantique est déficitaire, si le caractère explicit de la modalité de la tâche affecte la performance sur des tâches sémantiques, et, enfin, si un trouble sémantique affecte la performance syntaxique.

Les participants étaient 38 enfants avec TSA âgés de 8 à 17 ans (moyen d'âge : 11;4). Ce groupe d'enfants a varié pour ce qui est du degré de déficit pragmatique (mesuré par le *Children's Communication Checklist-Pragmatics*) et pour ce qui est du niveau non verbal (mesuré par les Matrices progressives de Raven), et a inclus, notamment, des enfants à haut fonctionnement aussi bien que des enfants à bas fonctionnement.

Un des avantages d'une étude d'enfants avec autisme de langue hébraïque est que la langue hébreu a des caractéristiques linguistiques et orthographiques particulières. L'hébreu écrit est caractérisé par un haut degré d'ambiguïté orthographique. Certaines voyelles sont rarement représentées à l'écrit, et même lorsqu'une voyelle est représentée, la lettre correspondante est généralement ambiguë entre plusieurs voyelles et consonnes. L'ambiguïté de l'hébreu nous a permis d'utiliser des épreuves approfondies additionnelles pour tester la sémantique et la syntaxe.

Le matériel d'évaluation a été développé pour suivre de près le Modèle d'accès lexical et le Modèle de lecture à double voie. Ces modèles ont été choisis puisqu'ils partagent des composantes qui pouvaient donc être testées à travers différents types de modalité de tâche (tels que des images, la compréhension auditive, la lecture). Etant donné les difficultés associées à l'évaluation du langage chez les enfants avec TSA, pouvoir varier la modalité des tâches a constitué un critère important. Dans cette étude 16 tâches expérimentales ont été utilisées (incluant des tâches de compréhension et de production du langage oral aussi bien que de la lecture). Cet ensemble particulier de tâches a été choisi pour rendre possible la différentiation entre des composantes sur la base de la performance sur des tâches spécifiques. Le but était de combiner la performance sur des tâches différentes afin d'arriver à des profils individuels identifiant la localisation exacte des troubles linguistiques des enfants avec TSA. Pour chaque tâche la réussite a été calculée de manière globale et une analyse d'erreur détaillée a été conduite. Les résultats de groupe ont été analysés (en termes de performance globale) et un profil linguistique des points forts et des faiblesses a été trouvé pour chaque individu. La performance dans le groupe TSA a été déterminée sur la base d'une comparaison avec des enfants à développement typique du même âge chronologique.

Il sera démontré que les capacités sémantiques des enfants avec TSA de cette étude étaient généralement intactes, bien qu'au niveau du groupe, leur performance était plus basse que celle des contrôles, sur toutes les tâches. Un petit nombre de participants n'a manifesté aucun trouble linguistique et aucun trouble de lecture. Aucun participant n'a manifesté un trouble de la composante conceptuelle et aucun n'a manifesté un trouble exclusif au lexique sémantique. Trois principaux profils lexique sémantique-langage ont été trouvés : 1) des participants manifestant une performance intacte pour toutes les composantes du Modèle d'accès lexical, 2) des participants manifestant un trouble dans le lexique sémantique ou son accès et qui avaient tous en plus un trouble syntaxique, et 3) des participants manifestant

aucun trouble de sémantique lexicale, mais qui avaient au moins un trouble syntaxique. Tous les participants avec un trouble du lexique sémantique ou avec l'accès à cette composante avaient en plus un trouble syntaxique (quelques-uns avaient par ailleurs une dyslexie), mais tous les participants avec un trouble syntaxique n'avaient pas forcément un trouble sémantique ou lié. Ce résultat questionne le bienfondé de l'utilisation large de la sémantique lexicale comme jauge des capacités linguistiques globales intactes des enfants avec TSA.

Cette thèse s'organise de la façon suivante: les premiers cinq chapitres fournissent des informations de base, y compris une présentation des procédures diagnostiques en vigueur en Israël ainsi qu'une revue de la littérature scientifique sur le langage dans l'autisme, et notamment des études ayant rapporté des résultats d'évaluation des capacités sémantiques et de la lecture, et, enfin, une présentation du cadre théorique de cette étude, les Modèles d'accès lexical et de lecture à double voie. Le chapitre six décrit la méthode utilisée pour adresser les questions de recherche: si il y a un trouble sémantique chez les enfants avec TSA et quelle est sa fréquence, si oui, quelle est sa nature et son influence sur les autres capacités linguistiques. Les résultats de l'étude seront présentés dans les chapitres sept à neuf et seront divisées entre les résultats de groupe, pour chaque tâche, et les profils individuels, basés sur une analyse approfondie des erreurs qui a servi à déterminer la performance intacte versus une performance déficitaire. Enfin, le chapitre dix discutera des résultats généraux et éléments de conclusion, dans la perspective de la littérature existante.

Introduction (English)

We know today that ASD is an organic neurological disorder; however, its precise etiology is not yet clear. Children with ASD have a wide range of deficits affecting their everyday lives; one of the most crucial deficits is a deficit in language. Variability between individuals with ASD is very high and research to date has had a hard time drawing conclusions about language in this disorder, resulting in a critical lack of appropriate diagnostic tools/methods and intervention programs targeted at linguistic abilities.

In many studies on ASD, lexical semantic abilities (most commonly a picture naming task) are used as a proxy for linguistic competence. Yet, past research on lexical semantic abilities has yielded conflicting results and conclusions are hard to make as the participants in these studies had different characteristics (e.g., IQ) and different tasks were used across studies (picture naming, semantic priming, and word picture matching, to name a few). In Sukenik (2012), I found that most participants with ASD made some form of lexical semantic errors, on several different language tasks. An outstanding question was whether this result was related to this particular group of children (N = 18) or these particular tasks (only two tasks testing lexical semantics), or whether lexical semantics is very widely (or systematically) impaired in children with ASD.

In order to evaluate semantic abilities and differentiate them from other related linguistic abilities, two models were used that have been verified through extensive research on children with aphasia, with dyslexia and with typical development (TD): The Lexical Retrieval model (describing how we go from a stimuli of a picture or an object to saying the word out loud) and the Dual Route to Reading model (describing how we go from a written word to saying the word out loud). These two models were selected as they have shared components and would allow us to differentiate between components based on performance

on the different tasks with the assumption that thru these tasks we would be able to pinpoint an exact location of linguistic impairment (if one exists) in children with ASD.

Using the Lexical retrieval model and the Dual route to reading model, this study investigated lexical semantics and its relation to other abilities in children with ASD, seeking to determine whether (and how widely) the semantic lexicon is impaired, whether task modality explicitness affects performance on semantic tasks and, finally, whether semantic impairment affects syntactic performance.

Participants were 38 children with ASD aged 8-17 (mean age= 11;4 years). These children varied for both the degree of pragmatic deficit (as measured by Children's Communication Checklist-Pragmatics) and for nonverbal level (as measured by Raven's Progressive Matrices), and included, notably, both high-functioning and low-functioning children.

One of the advantages of a study of Hebrew-speaking children with ASD is that the Hebrew language has particular linguistic and orthographic characteristics. Written Hebrew is characterized by a high degree of orthographic ambiguity. Some vowels are rarely represented in writing, and even when a vowel is represented, the corresponding letter is usually ambiguous between several vowels and consonants. The ambiguity of Hebrew enabled us to use additional, in-depth linguistic tasks for testing semantics and syntax.

Testing materials were developed to adhere to the Lexical retrieval model and the Dual route to reading model. Given the difficulties associated with evaluating language in children with ASD, varying task modality constituted an important goal. In the current study 16 experimental tasks were used (including oral language comprehension and production as well as reading). The particular array of tasks chosen was designed to allow for it to be possible to differentiate between components based on performance on the specific tasks. The aim was to combine performance on the different tasks in order to arrive at individual

profiles identifying exact location(s) of linguistic impairment in children with ASD. For each task accuracy was calculated and detailed error analysis was conducted. Group results were analyzed (general performance) and a linguistic profile of strengths and weaknesses was found for each individual. ASD performance was determined based on comparison to groups of typically developing children of the same age.

It will be shown that overall, the semantic abilities of most children with ASD in this study were found to be intact, although as a group, the ASD group had lower performance than controls on all tasks. A small number of participants were found to have no linguistic or reading deficit. None of the participants was found to have an impairment in the conceptual component and none was found to exhibit an exclusive semantic lexicon deficit. Three main lexical semantics-language profiles were found: 1) participants who showed intact performance on all the Lexical retrieval model components, 2) Participants who were found to have an impairment in the semantic lexicon or in accessing it and all had an accompanying syntactic impairment, and 3) Participants who showed no lexical semantic impairment but were impaired in at least syntax. All participants with a semantic lexicon or access to the semantic lexicon impairment were also found to have a syntactic deficit (a few also had dyslexia) but not all participants with a syntactic deficit were found to have impaired semantics or semantic related deficit. This result questions the legitimacy of the wide use of lexical semantics as an indicator of intact global linguistic abilities in children with ASD.

This thesis is organized in the following way: the first five chapters provide background information, including both an outline of diagnostic procedures in Israel as well as a review of previous studies assessing language (specifically semantic abilities) and reading in children with ASD, as well a presentation of the theoretical framework for this study, The Lexcial retrieval model and The Dual route to reading model. Chapter six describes the method used to address the research questions of whether and to what extent

children with ASD have a semantic impairment and if so what its nature is and what its influence on other linguistic abilities is. Study results will be presented in chapters seven to nine and will be divided into group results for each task followed by individual profiles including in depth error analysis to determine intact versus impaired performance. Finally, chapter ten will discuss general results and conclusion in line with previous studies.

1. ASD and Language

1.1 ASD definition and diagnosis

Autism spectrum disorder (ASD) is one of the fastest growing epidemics in the western world. The following chapter will focus on the definition and diagnosis of ASD as it is presented in the Diagnostic and Statistical Manual of Mental Disorders (DSM–V) as this was the diagnostic tool used to diagnose the current research participants.

The diagnostic method for autism has seen many changes that reflect growing understanding of the disorder. In the first two DSM guidelines that were published (1952, 1968, respectively) autism was classified as a subcategory of schizophrenia. Only in the DSM- III (1980) did autism receive for the first time its own category of *Infantile Autism* and here language was also addressed for the first time. Language was described in the following way: "if speech is present, peculiar speech patterns such as immediate and delayed echolalia, metaphorical language and pronominal reversal". The DSM III-R (1987) further defined the autism spectrum as having "qualitative impairment in verbal and nonverbal communication and in imaginative activity".

The DSM-IV, published in 1994 (and the DSM-IV-R, in 2000), coined the term *Autism Spectrum Disorders* and mentioned the variety and heterogeneity of the disorder. Recent research conclusions have led to the publication of the DSM-V, which includes all previous subtypes under one name – Autism Spectrum Disorder. The biggest difference between the DSM-IV and DSM-V, is that the DSM-V places the autism spectrum disorder inside the broader category of neurodevelopmental disorders and entails that a delay in language is no longer a key characteristic of autism. Under the DSV-V the clinician must specify whether the child with ASD is with or without accompanying intellectual disability and with or without accompanying language impairment. The changes made to the diagnostic importance of the language criterion caused a major public debate as some individuals with

high functioning autism (HFA) might today not meet the criteria for autism but be diagnosed as having a "social communication disorder".

In order to qualify for an ASD diagnosis, an individual must have persistent deficits in social communication and social interaction across multiple contexts and restricted, repetitive patterns of behaviour, interests, or activities. For each of these a severity level should be established based on the level of everyday functioning. Symptoms must be present in the early developmental period and cause clinically significant impairment in social, occupational, or other important areas of current functioning.

Due to the big increase in autism rates (4.5 /1000 Ministry of health, Israel 2017), recent years have seen a big lobbying group of parents together with professionals in Israel that have brought the autism diagnosis into a clear and well established law. Diagnosis of a child with autism, by Israeli law, must include physical, neurological and developmental assessment (cognitive and emotional). Only certified medical personnel (a child/ adolescent psychiatrist, a paediatrician with at least three years of experience or a paediatric neurologist) may diagnose. In addition to a medical diagnosis, the diagnosis needs to be confirmed and agreed upon by a clinical psychologist, developmental psychologist or educational psychologist with relevant training, following DSM-V guidelines. Recently, the law has been revised such that for young children the diagnosis needs to be re-evaluated every three years; if symptoms persist after age seven, only then will the diagnosis be considered stable with no need for further re-evaluation.

Diagnostic personnel are instructed to use standardized tools that have been translated into Hebrew – the Mullen Scales of Early Learning (MLU); Bayley Scales of Infant and Toddler Development, Wechsler Preschool and Primary Scale of Intelligence; Wechsler Intelligence Scale for Children (WISC); Adaptive Behavior Assessment System; Vineland Adaptive Behavior Scale; Childhood Autism Rating Scale (CARS); Social Communication

Questionnaire (SCQ); Social Responsiveness Scale. The use of the Autism Diagnostic Interview, Revised (ADIR - Rutter, Le Couteur, & Lord, 2003) or the Autism Diagnostic Observation Schedule (ADOS - Lord et al., 2000) is optional as these are not available in most clinical facilities.

Every child that receives an autism diagnosis has all the required scores, but, by law, the parents are not obliged to give the reports to the schools (only to the SHEFI – the educational psychologist services in each district). The policy of the SHEFI and the special education department at the ministry of education states that no diagnostic data should be passed on to researchers even if they have been granted a research permit in the school. In cases in which the teacher is in possession of the child's diagnostic report, she/he may provide the researchers with the scores if the parents give their consent or if the ministry of education scientific board allows for these scores to be collected, but as this is not the usual case, obtaining the diagnostic characteristics of each child is usually impossible. Reaching out to parents as a researcher and asking for the child's diagnostic report is explicitly forbidden by formal protocol.

1.2 Language in ASD

The view of language in ASD has also seen changes over the years. The first studies reported that children with ASD have vast deficits in pragmatics while having intact phonology, syntax and semantics. In recent years, research has shifted towards identifying subgroups of children with autism, some of whom have normal structural language capabilities while others exhibit impaired structural language abilities.

1.2.1 Pragmatics

Pragmatics is the study of the aspects of meaning and language use that are dependent on the speaker, the addressee and other features of the context of utterance. Many researchers have found that pragmatic abilities (defined as difficulty to understand metaphors, irony and

jokes, trouble adjusting one's conversational contribution, non-adherence to Grecian maxims and problems with the detection and avoidance of faux pas) were impaired in children with ASD (see Kissine 2012 for detailed review). Recently, different researchers have been testing different aspects of pragmatic functioning and have been finding that not all aspects of pragmatic functioning are impaired. Chevallier et al., (2009) tested children with Asperger's syndrome on grammatical prosody comprehension (interpretation of word stress; grammatical pause; discrimination of the question contour) and found that the ASD group performed similar to age equivalent TD children. Kissine et al., (2015) tested a group of children with ASD (7-12 years) on an indirect speech act comprehension task. They found that the ability to understand context based indirect requests seemed to be preserved in this group of children. On the other hand, de Villiers et al., (2010) found that children with ASD seemed to have specific difficulty properly using full and informative sentences as well as null complements.

Boucher (2003) and Groen et al., (2008) in their reviews of linguistic studies in autism, characterized the language of children with autism as being instrumental rather than social in its intention, with content that is at times repetitive and egocentric. Hurtig et al., (1982) (later confirmed by Rogers et al., 2012) found that children with autism tended to use persistent and preservative questioning. This was found to be used as a means of initiating interaction or getting attention and less for the purpose of requesting information.

The source for the vast pragmatic impairment seen in most children with ASD has received different interpretations. For example Rogers et al., (2012) interpreted pragmatic deficits as part of behaviours associated with anxiety. Others have attributed pragmatic deficits as part of impairment in Theory of mind (ToM) (Yirmiya et al., 1998) or in the inability to shift perspective and thus part of a more general cognitive deficit (Baron-Cohen, 2000).

1.2.2 Phonology

Phonology is defined as the study of sound structures wherein deficits may appear in articulation (deficits in sound production – sounds may be substituted, omitted, added or changed) or /and phonological processes (deficits in sound patterns). Phonologically correct echolalia (characterized as the unsolicited repetition of vocalizations made by another person) that are considered common in children with ASD has been interpreted as a sign for intact phonological articulation and phonological processes (Tager-Flusberg, 1996).

Articulatory distortions have been found in some children with autism in the studies by Shriberg et al., (2001) and Cleland et al., (2010). In contrast to these findings Tager-Flusberg & Cooper (1999) tested a group of verbal children with ASD and found that a quarter of these children had language scores within the normal range, while the rest of these children had scored significantly lower than the mean on all linguistic tasks – except on the articulation measure on which they were found to have age equivalent scores. Kjelgaard & Tager-Flusberg (2001), who tested a large sample (*n*=89) of children with ASD, also found all of them to have good articulation skills.

Phonological processing has been tested by different researchers mainly by using a nonsense word repetition task. Tager- Flusberg (2006) tested 35 children with HFA (mean age = 10; 4, *SD* 1;9) with an average nonverbal IQ of 83 on three subtests from the Comprehensive test for phonological processing (digit memory, rapid automatic naming and non-word repetition). Results found 15 children that had scores that were age equivalent or borderline on non-word repetition, while 20 were found as significantly impaired. Error analysis revealed that all ASD participants repeated the correct number of syllables and that errors were either phoneme deletion or phoneme substitution. Similar results were found by Bishop et al., (2004) and Riches et al., (2011) who tested children and adolescents with ASD on a non-word repetition task. Bishop et al., (2004) interpreted the poor performance of children with ASD as a deficit in phonological processing together with a deficit in working

memory. Riches et al., (2011) found that children with ASD had specific difficulties with syllabic structure and produced many phonemic substitutions. Tuller et al., (2016) found that children with ASD and language impairment (ASD- LI) and children with Specific language impairment (SLI) used the same strategies to avoid syllabic complexity. Geurts & Embrechts (2008) reported that preschool-aged children with ASD found to have language impairment seemed to show a phonological impairment profile similar to children with Specific Language Impairment (SLI), which includes phonological and syntactic impairment. These same children when tested at school age several years later seemed to no longer resemble the impairment profile of SLI but rather had more significant difficulties in higher order processing as well as pragmatic impairment. The authors interpreted these findings as evidence that phonology may be less impaired than other areas of language, but that conclusions are age-related. Lord & Paul (1997) and Sheinkopf et al., (2000) found that children with ASD tended to use intonation and stress patterns in an atypical way.

It seems that phonology may be spared in a subgroup of children with ASD who have no other linguistic impairment, but that articulation and phonological processing may be, independently or not, impaired in many children with ASD.

1.2.3 Morphosyntax

Syntax is the set of structural rules governing the composition of clauses, phrases; the term morphosyntax is used to encompass both syntactic rules and inflectional rules, which determine the form that words take due to their occurrence in a particular syntactic context (e.g., agreement marking) in any given natural language. Research results on morphosyntactic abilities in children with autism have shown mixed performance, some claiming these children have intact abilities while others have found them to be severely impaired.

Some studies have found ASD participants to display a pattern of impairment opposite of young typically developing children wherein syntactic expression abilities are better than reception abilities (Ahadi et al., 2016; Ellis et al., 2010; Kover et al., 2013; Volden et al., 2011), but this conclusion is not a firm one (see Kowk et al., 2015). In recent years, research on syntax in ASD has been growing, although most studies have concentrated on very specific syntactic abilities.

Among the specific syntactic abilities investigated in children with ASD have been pronouns, relative clauses, and verbal inflection. Deficits in comprehension and production of pronouns, have been considered to be a common linguistic characteristic of children with ASD, regardless of whether data was collected as speech samples (Evans & Demuth, 2011; Naigles et al., 2016) or as part of a structured task (Novogrodsky, 2013; Perovic et al., 2013). Comprehension and production of relative clauses (especially object relative clauses) were found to be impaired in a large number of studies (Durrleman et al., 2016; Riches et al., 2010; Schaeffer, 2016, 2017). Modyanova et al., (2017) and Park et al., (2012) found that a subgroup of children with ASD and language impairment -LI (Modyanova et al., 2017: ASD+LI) had significantly lower scores than controls on non verbal IQ (NVIQ) (matrices of the Kaufman Brief Intelligence Test -KBIT), Vocabulary part of the KBIT, Peabody Picture Vocabulary Test (PPVT) and Test for Reception of Grammar (TROG); Park et al., 2012: Language samples and the 'Wugs task') had significant difficulties in the production of verbal inflection, but that their errors differed in nature from TD and children with SLI, both of the latter groups usually had ommittion errors while the ASD+LI children had omission errors but also had errors of using the wrong tense which was not found in the other two groups.

Boucher (2003) summarized the linguistic characterization of the different subtypes of autism, showing that syntactic impairments had been found to usually be absent from the linguistic profile of children with the label 'Asperger’s syndrome,' but very much present in

children with HFA and low functioning autism (LFA). She also speculates that many syntactic errors and anomalies in inflectional categories are observed in spontaneous speech but not always in clinical testing.

Eigisti & Bennetto, (2009) argued that contradicting results in different studies are a result of different age groups (with younger children achieving lower scores) and method of data collection: a highly structured task (which typically biases the ASD group towards better performance), or a more open and qualitative task.

In summary, although in the past, research seemed to imply that syntactic acquisition was merely delayed; recent research has found that there is a subgroup of children with ASD who are not only delayed but also impaired in their syntactic abilities.

1.3 Summary

According to the DSM-V, an individual may be diagnosed with ASD with or without having structural language impairment. In Israel the common method of diagnosing a child with ASD is by using the DSM guidelines. Although obtaining the exact diagnostic data of children with ASD in Israel is extremely difficult, due to the well established law concerning such information, a high rate of credibility can be placed in these diagnoses. Studies on language in children with ASD on morphosyntax (and phonology) seem to generally find two groups of children: children with ASD-LN (in the area tested in each specific study) and children with ASD-LI. The nature and origin of impaired language in the latter is an ongoing debate for all areas of linguistic research.

2. Reading in ASD

2.1 Introduction

The Dual route to reading model as presented in Section 3.3 was chosen for this research as it has shared components and theoretical functions with the Lexical retrieval model. Research on reading abilities of children with autism is scarce, which is why the current review includes studies regardless of their publication date. Research into reading patterns offers a window to yet another cognitive mechanism that may help in understanding the underlying deficits and strengths of children with autism. For our study, reading provides another angle from which to test different aspects of comprehension and production in relation to all aspects of language, lexical semantics, but also phonology, syntax, and pragmatics.

Early studies (Kanner, 1943; Burd & Kerbeshian, 1985; Whitehouse & Harris, 1984; Snowling & Frith, 1984, 1986) typically found children with autism to have 'hyperlexic' reading with poor comprehension abilities but intact decoding abilities. Hyperlexia (defined as a superior ability to read words at least two SD above full scale IQ levels, as described by Grigorenko et al., 2003) was thought of as being very common in children with autism. Nation (1999) explains this as a result of a number of shared characteristics between hyperlexic readers and individuals with autism: a tendency to be interested in local rather than global features and a preoccupation with text and reading at a very early age. Today it is clear that although there might be a subgroup of children with autism and hyperlexia, not all children display this particular reading pattern.

Most previous studies were either conducted in English or Swedish making it hard to generalize the results on other languages with different orthographic characteristics. Another constraining issue is the fact that all studies found tested children with HFA, most of them within the normal range of verbal and / or nonverbal scores. There has also been no

longitudinal study tracking the development of reading abilities in children with autism and thus we can only assume that their reading development follows the same trajectory as TD children, but we cannot know for sure.

2.2 Reading accuracy versus reading comprehension

Reading accuracy, also referred to as word decoding is the ability to associate each letter (or letter combinations) with the corresponding sound, and the ability to correctly map these sound strings in the correct order to produce the target word (for a more detailed review see Section 3.3 regarding the stages of reading). Most studies testing word reading skills have found children with autism to have age equivalent reading accuracy levels (Asberg & Sandberg, 2012; Jacobs & Richdale, 2013; Goldstien et al., 1994; Gorigorenko et al., 2002; Happe et al., 2006; Huemer & Mann, 2010; Jones et al., 2009; Locas & Norbury, 2014; Minshew et al., 1994; Newman et a., 2007; Nation & Norbury, 2005; Norbary & Nation, 2011; O'connor & Klein, 2004; Ricketts et al., 2013), although some have found a subgroup of children with autism as having poor decoding skills (Asberg & Sandberg, 2012; Asberg et al., 2010; Locas & Norbury, 2014; Whitehouse et al., 2006). In all these studies, the ASD participants had normal verbal IQ (VIQ) and full scale IQ (FSIQ) scores.

Reading comprehension, on the other hand, was found to be highly impaired in numerous studies, all testing children with HFA (Asberg et al., 2008; Frith & Snowling,1983; Huemer & Mann, 2010; Jones et al., 2009; Minshew et al., 1994; Nation et al., 2006). Several studies have suggested that this pattern of poor comprehension alongside good decoding skills may be a result of other 'autistic' features such as integrating information in context (Frith, 2003), low verbal scores (Mirenda & Erickson, 2000), general communication impairment (Nation & Norbury, 2005) or an overall language impairment affecting reading comprehension (Tager-Flusberg & Joseph, 2003).

Asberg & Sandberg (2012) tested 15 Swedish children with ASD (aged 10-15, *M* = 12;7) on word reading, NVIQ (The Wechsler Abbreviated Scale of Intelligence - WASI matrices), Phonological processing (phonemic awareness task), PPVT and Rapid naming. They were compared to a group of age-matched TD children. The ASD participants were divided into two groups based on their reading scores – a group of children with ASD and age equivalent reading scores and a group of children with ASD and reading scores that were significantly lower than age equivalent controls. The group of children with ASD and 'poor' reading scores were found to have low scores on all other variables tested except the NVIQ (which was age equivalent for all children). The authors then compared the group of 'poor readers' to TD children who were younger in age and found no significant differences between the groups. The authors interpret these results as showing a delay in word reading but not a deficit.

In summary, it seems that, unlike TD children, reading accuracy and reading comprehension doesn't always develop synchronically in children with ASD and that language plays a role whose extent is yet unclear.

2.3 Relations between language and reading

The few studies testing reading abilities in children with ASD, have tried to find different predicting and explaining factors for their results. In most cases, reading abilities were found to be highly correlated to linguistic functions.

Brown et al (2013) reviewed 36 studies comparing children with autism and different control groups on reading abilities and found that the strongest individual predictors of reading comprehension was semantic knowledge and word decoding skills. Davidson & Weismer (2014) tested 127 children with ASD on reading skills. They found that reading abilities were associated with nonverbal cognition and that expressive language as well as social abilities were negatively related to alphabet knowledge. Nation et al. (2006), compared

41 children with ASD aged 6-15 years (*M* = 10;3) to a group of age equivalent TD children. This study found a strong correlation between poor oral language skills (as measured by The British Picture Vocabulary Scale- BPVS-II and the WISC- III) and poor reading comprehension. Ricketts et al., (2013) tested 100 adolescents with ASD aged 14-16 years (*M* = 15;6) on word recognition, oral language, reading comprehension , social behaviour and social cognition. Regression analysis showed that both word recognition and oral language explained the variance in reading comprehension. Norbury & Nation (2011) and Asberg et al., (2010) found similar results. Jacobs & Richdale (2013) tested 42 children with HFA aged 6-8 (*M* = 7;8) who had normal range VIQ and FSIQ and compared them to a group of age equivalent TD children on tasks testing IQ, phonological processing, oral language and vision in order to try and predict decoding and reading comprehension. Regression analysis found that IQ, phonological processing and syntax predicted decoding scores for all groups but that semantics (as tested by PPVT, The Expressive Vocabulary Test - EVT, Evaluation of Language Fundamentals - CELF and the Renfew bus story) was a predictor for both decoding and comprehension only for the TD children and not the ASD children.

Locas & Norbury (2014) tested 50 children with autism (half with normal language scores and half with scores indicating language impairment) on reading comprehension of sentences and texts. They found that children with normal language (ASD-LN) demonstrated syntactic and semantic facilitation skills similar to age-matched TD controls and no differences were seen in their reading comprehension. On the other hand, in the group of children with ASD-LI, it was found that there were many children who were able to read only at a single word level and that those who were able to read sentences had better semantic scores but were less sensitive to syntactic structures than the ASD-LN. At the text level, the strongest predictor for reading comprehension was vocabulary knowledge. Lindgren et al., (2009) also divided a group of children with ASD-LI and ASD-LN and compared their

performance on a reading comprehension task to that of children with SLI. They found that ASD-LI group and the SLI group had equivalent reading comprehension scores while the ASD-LN group scored significantly higher than both of these groups.

In summary, it seems that linguistic abilities are a significant factor in reading ability in children with ASD and that in children with ASD and linguistic impairment, reading scores are found to be lower.

2.4 Summary

Most previous studies on reading in children with ASD were conducted in English or Swedish and with participants with HFA only, making it difficult to draw general conclusions. The available studies show that good reading accuracy scores alongside poor reading comprehension scores seem to be a common profile in children with ASD, although differences between individuals are very big. Linguistic abilities (especially lexical semantics) seem to influence reading abilities to some extent, but the exact relations between the two are as yet unclear.

3. Theoretical framework

3.1 Semantic Model and possible impairments

Semantics refers to meaning as it is specifically encoded in language. Semantic knowledge is different from thoughts and concepts, it is the knowledge of what aspects of meaning receive linguistic markings in a particular language context and how that encoding is carried out. Semantics is the exact, literal meaning of words and their interrelations, while pragmatics focuses on the inferred meaning that the speakers and listeners perceive. Our understanding of words and their meanings is influenced by many factors such as grammar, phonology, and context to name a few. Research in typically developing children and patients with brain damage has generated much debate about how exactly to test and differentiate between semantic problems and other interfering problems.

Semantics is part of all linguistic levels, as meaning is part of morphemes, words, phrases and sentences. Most linguistic studies on semantics put their focus on the meaning of words (lexical semantics) and how these meanings are put together in phrases and sentences (compositional semantics). The present study concentrates on lexical semantics; when referring to semantics in the following chapters, we will therefore mainly refer to lexical semantics. The following chapter outlines the semantic component's role in language production and comprehension and reviews the problems that might occur when part or all of this system is impaired.

The semantic component is part of any type of communication that we engage in, be it speech production, speech comprehension, reading or writing. Ellis and Young (1988) have noted numerous researchers that have come to the conclusion that there is a correlation between the number of semantic errors a person makes in production and the degree of impairment in comprehension. This serves as the basis for the assumption that the semantic component is shared for both production and comprehension.

Since accessing the semantic component without involving any other brain function is virtually impossible, we will rely on two accepted models, the Lexical retrieval model and the Dual Route to Reading model, in order to present the semantic component's role, features and impairments. These two models are products of research mainly in the area of brain damage and they have many overlapping components. Although extensive research in aphasia and developmental dyslexia (Ellis and Young, 1988; Butterworth, 1989; Levelt 1992; Ellis et al, 1992; Nickles,1997; Dell et al, 1997; Zorzi et al, 1998; Friedmann & Gvion, 2001; Friedmann & Nachman-Katz 2004; Howard & Gatehouse, 2006; Coltheart, 2005; Biran and Friedmann, 2005; Friedmann an&d Lukov, 2008; Ziegler et al., 2008; Friedmann et al 2013; Friedmann and Coltheart 2016) have been able to validate these models by providing empirical support for their predictions for the different repercussions of impairment at

different locations, these models have rarely been applied to other cognitive disorders (see Martin et al, 1994 on SLI; Potter et al,. 1984 and Wambaugh et al, 2001 on bilinguals, and Plaut & Booth, 2000, on TD).

3.2 Lexical retrieval model

The most common view in research on lexical retrieval is that this is a multi-step process (Levelt 1992) involving retrieving a word from tens of thousands of different alternatives and then phonologically encoding it (Butterworth, 1989). This view has been validated by observing that some aphasic patients have semantic errors but not phonological errors, while others show the opposite impairment (Nickles, 1997). Studies on states of "Tip of the tongue" (a person knows the word but has temporary retrieving difficulties) in healthy adults has also shown that mistakes can be classified as either semantic (*I sent a fax, ah, no, an email*) or phonological (*deand end*..) and thus supporting the view that these are two distinct places of impairment (Friedman et al., 2013). Friedmann, Biran, and Dotan (2013), based on the work of previous researchers, summarized the lexical retrieval model as in Figure 1.

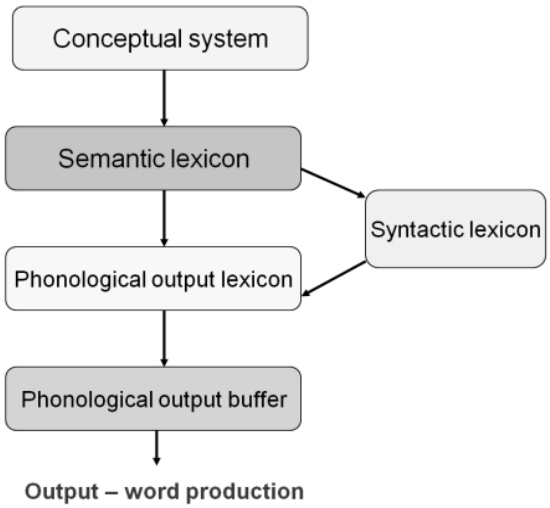


Figure 1. Stages in lexical retrieval

According to this model, the first stage of lexical retrieval is the conceptual system wherein a non- lexical representation is formed. This representation typically includes a visual image, semantic properties, its uses and maybe relations to other objects or people. This concept can be self-triggered in an individual from his/her own idea, or the result of seeing a visual image, or an actual object (Carmazza 1997; Friedmann, Biran and Dotan, 2013). The non-lexical concept that was formed in this way will move on to the semantic lexicon where it will activate a lexical semantic representation. Butterworth (1989) and Levlet (1992), considered the semantic lexicon as a "hub" that mediates between the conceptual system and the syntactic and phonologic lexicons.

The semantic lexicon is organized by semantic categories and semantic relationships between words – words can have close or far semantic relationships with other words (Carmazza 1997). The basic assumption is that we categorize words in order to be able to access them faster. We may categorize them according to topic, morphology, syntax, phonology or personal experience (Cruse, 1986). One of the theories trying to describe how the semantic lexicon is organized was the Full Listing Hypothesis that stated that for every word a person knows there is a separate entry in the lexicon (Butterworth 1983). However this theory is hard to accept when considering languages like Turkish or Finnish. Nickles (1997) presents the example shown in Hankamer (1989, cited in Nickles, 1997) of a single noun in the Turkish language that could be used in four million different conjugations making it implausible that we store such information in the semantic lexicon. It seems that words are most likely represented in their root forms and the lexicon has a set of rules and affixes that it can act upon. In addition, we might also have complete word forms especially (and only) for those words that don't fit the different rules we possess (Nickles, 1997). Evidence from impaired patients has shown that there is a frequency affect in the lexicon – words that are more frequent will be easier to retrieve (Friedmann et al 2013; Ellis and Young 1988; Levlet

1992; Friedmann & Coltheart, 2016). Howard and Gatehouse (2006) found that the semantic lexicon also has an imagenability affect – words that are more imaginable, meaning they are more concrete, are more easily retrieved than words that are abstract.

After the semantic lexicon, the next stage is where the semantic representation activates the lexical phonological representation in the phonological output lexicon – the number of syllables, stress pattern, phonemes and their relative positions (Levelt, 1992). At the same time, the semantic representation also activates the syntactic lexicon, which holds all the syntactic properties (verb inflection, gender, thematic roles) of the activated word (Friedmann et al., 2013).

The activation is in turn transferred from the phonological output lexicon to the phonological output buffer, which has two functions: maintaining activation and composition (Friedmann et al., 2013). The phonological output buffer is a phonological short-term storage space, which holds the phonological representation that arrives from the phonological lexicon until the word is produced (Butterworth, 1989; Dell, 1988; Levelt, 1989, 1992).The final stage happens when the phonological output buffer sends the phonological representation of the word to phonetic encoding, the stage that prepares the phoneme string for articulation and sends it to the motor system.

Recent work by Ellenblum (2013) has provided evidence for the existence of the semantic lexicon and its position in the model in Figure 1 by showing a dissociation between the semantic lexicon and the syntactic lexicon (one patient showing intact semantic abilities but impaired syntactic abilities, while the other patient showing the opposite pattern), a dissociation between lexical semantic and sentence level knowledge, a dissociation between lexical semantic and conceptual knowledge (a patient who had an impairment whenever words were involved, but not when the stimuli was nonverbal), and a dissociation between the semantic lexicon and the phonological lexicon.

Since the Lexical retrieval model, for oral language, in Figure 1 has many parts in common with the Dual route model, for reading, and since this thesis includes several tasks that involve reading, we will present this model next and only after present the possible locations of impairments for both models together.

3.3 The Dual route to reading model

Reading, according to Coltheart (2005), is information processing which transforms a written target to speech or a written target into meaning. The Dual route to reading model as it appears in Friedmann and Coltheart (2016) is presented in Figure 2.

According to the Dual route model, when a person is presented with written stimuli, his brain has two alternative routes (the Lexical or the Non-lexical route) it can follow in order to process the target (Coltheart 2005). If reading is done using the Lexical route, the stimuli will go straight down through all stages of the model as well as through the conceptual and semantic lexicon. On the other hand, reading through the non-lexical route means that after a stimuli has been processed in the Orthographic-visual analyser and the Orthographic buffer it uses a side route involving the Grapheme-Phoneme Converter. A "grapheme" is any letter or letter sequence that represents a single phoneme. Phonemes are the distinctive sounds that a language uses. Phonemes are units of the spoken language whereas letters are units of the written language and there is not a one-to-one correspondence between them.

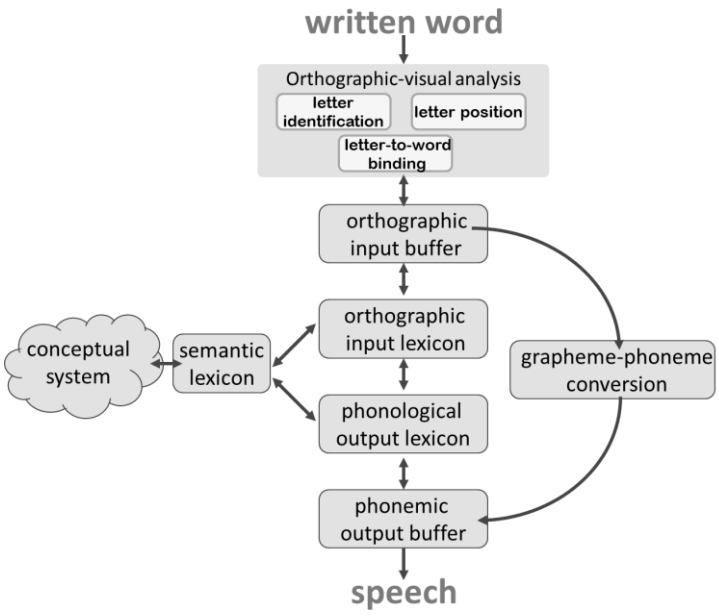


Figure 2. The Dual route to reading model

In the first stage of this model, the word enters the Orthographic visual analyser that is responsible for letter identification (identifying a certain letter regardless of font/size), letter position (where a certain letter is positioned inside the word – *calm* as opposed *to clam*) and letter to word binding (knowing that a certain letter is part of the first word in the sentence and not the second) (Friedmann & Coltheart, 2016). After the Orthographic visual analyser, the word moves on to the Orthographic output buffer which is a short term memory storage component where it will be available for accessing in the next stages. At this point, reading can either be done via the Lexical route or the sub-lexical route. If reading is done via the Lexical route, then the word passes on into the orthographic input lexicon. This lexicon does not contain the meaning or the sounds of the word, but rather knows to identify the word as such and whether the word is known to the reader or not. This lexicon is organized by frequency (Ellis & Young, 1988; Friedmann & Coltheart, 2016).

Before reaching the phonological output lexicon, the target word takes a side step and enters the semantic lexicon and the conceptual system. The orthographic output lexicon activates the semantic lexicon, which in turn activates the conceptual system. The conceptual

system is where concepts for words, pictures, objects and auditory information are stored. The semantic lexicon (see Section 3.1) on the other hand is a place where the words and their meanings are stored and arranged according to their meaning.

Accessing the semantic lexicon and the conceptual system makes the process of recognizing the words and so knowing how to read them into a fast and efficient process; but, if the word is not known, then the semantic and the conceptual systems are at a loss (Friedmann and Coltheart 2016).

The next stage in the lexical route is the phonological output lexicon which contains information about the sounds of vowels and consonants, stress and number of syllables (Dell, 1988). The final stage is the phonological output buffer, which is a short term component that holds the information from former stages and assembles the phonemes into words. It is in this stage that morphologically complex words are assembled (Friedmann & Coltheart, 2016; Zorzi et al., 1998; Dotan & Friedmann, 2015).

When a word that is not known enters the model, it is read via the sub-lexical route. The first two stages are identical to the lexical route – the orthographic visual analyser and the orthographic input buffer. Then the sub-lexical route goes into the grapheme phoneme converter. Here letters are converted into graphemes (the written form of a phoneme) and grapheme to phoneme rules applied in order to know how to read the word. The resulting phonemes are then sent in the phonological output buffer and assembled there to create the target word (or non-word) (Friedmann & Coltheart, 2016; Zorzi et al., 1998). In most cases, skilled readers will read using the lexical route as this would be the fastest route. If a word is a low frequency word, meaning it is present in the reader's lexicon, but it isn't used frequently, it will be read using the lexical route, but it will take longer to reach the target. If a word does not exist in the reader's lexicons, then it will be read through the sub-lexical route.

Both models present a complex and multi-stage process in speech and in reading. The process of going through these stages in speech production and reading in typically developing children and adults is a fast and efficient process, but, each component can be impaired individually, access to a component can be impaired, and there can be multiple impairments in a single patient; each of these possibilities will be reviewed in the following section.

3.4 Location and manifestation of possible impairments

When referring to the possible location of impairment we will refer to the Lexical retrieval modal (Figure 1) and the Dual route to reading model (Figure 2) and describe the symptoms that are expected and that have been found both within speech production and word reading. When looking at this model, the higher up (or the closer to the beginning of the process) the location of the impairment is, the wider will be the impact on speech production and comprehension.

The conceptual system is the first part of the model to be activated in all forms of communication. A deficit in this component will cause lexical retrieval problems, but it will also cause significant problems in comprehension, reading and writing, auditory processing and nonverbal situations (Friedmann et al., 2013). A person with impairment in the conceptual system may have naming errors that are not related to each other ("*bridge*" for "*grapefruit*"). Since the impairment is in the conceptual system they will most likely fail in verbal tasks as well as in tasks involving concepts such as choosing an odd picture from a group of pictures or on a picture association task (which picture best matches another picture). They will however most likely not have any phonological errors and so might not have any trouble at all completing tasks which require no understanding, such as non-word reading or non-word repetition tasks (Friedmann et al 2013).

The semantic lexicon is the next stage that might be impaired according to the Lexical retrieval model. Deficits in the semantic lexicon are also known as "semantic anomia". As shown before, since the semantic lexicon is shared for speech production, reading and presumably speech comprehension, a deficit in this component would result in impairments of word retrieval, reading, and auditory comprehension. The most common mistakes that semantic anomia patients exhibit are semantic paraphasias – producing a word that is semantically related to the target word. This could happen in a naming task or in spontaneous speech. Depending on the extent of the impairment, some patients might show an imagenability effect, producing concrete words better than abstract words or they might show a prototypical effect (Cohen-Shalev & Friedmann, 2011), where more typical items of a category were produced (apple) instead of less typical ones (plum). A phenomena that has received extensive research is the fact that the semantic lexicon may be only partially impaired, thus resulting in Category Specific impairments. The most common case of Category Specific anomia is the disproportionate ability to name living things compared to nonliving things and the opposite (Mahon & Caramazza, 2009). Lyons et al. (2002) presented several cases of patients with such a deficit: for example a patient who could name body parts, fruits, vegetables, vehicles, pasta, furniture and colors with no errors but was unable to name any famous faces or places. Lyons et al. (2002) point out that even in these kinds of impairments there are different degrees of impairments – for example a patient who could not name proper nouns, but could describe them, and hence could access their semantic meaning, alongside a different patient who could name proper nouns, but could not retrieve any information regarding those nouns.

Partial versus complete impairment in lexical retrieval difficulties was further investigated by Jefferies et al., (2008). They tested patients with Semantic Dementia (SD) and patients with aphasia following a stroke on a picture naming task and the effect of cumulative

phonemic cueing on this task. They found that for the patients with aphasia cumulative phonemic cueing improved their naming abilities dramatically; this results means that semantic knowledge in these patients was intact, but there was a problem accessing it. The patients with SD, on the other hand, showed hardly any effect for cumulative phonemic cueing; it seems that for these patients semantic knowledge of the target words was lost. The conclusion from both these studies is that there are two very important players inside the semantic lexicon – semantic representations and executive control of semantic processing (as coined by Jeffries et al., 2008), meaning access to this semantic knowledge, and that each of these can be impaired independently.

Another important aspect of patients with category-specific semantic impairments is that they have difficulty distinguishing between basic-level items inside the impaired category but do not necessarily have problems assigning items they cannot identify to the correct superordinate level category (e.g., they may know that a picture of a dog is an animal, but do not know which kind of animal it is) (Mahon & Carmazza, 2009). A deficit in the semantic lexicon is a deficit in verbal understanding, but since the conceptual system in this case is intact, individuals with semantic lexicon deficits should do well on picture tasks (such as Odd one out or picture association) but they will most probably fail on this same task when it is presented in words, meaning they would probably show difficulties in written and spoken versions of the same task they had succeeded on in pictures (Friedmann et al., 2013). If impairment is confined to the semantic lexicon, we do not expect to see phonological impairment (phonological paraphasias in naming or in spontaneous language, or phonological reading errors) and these individuals most likely will be able to read and repeat non-words correctly (Ellis & Young, 1998; Friedmann & Coltheart, 2016).

The next possible location of impairment in the model is the phonological output lexicon. If the conceptual system and the semantic lexicon are intact, then these subjects

should have good conceptual and verbal comprehension, good reading comprehension in silent reading and good auditory comprehension, but impairment mainly in production (Ellis and Young, 1988; Nickles, 2014; Biran & Friedmann, 2005). These patients usually have good non-word repetition and reading, as these don't involve the lexicon (Friedmann et al., 2013). Reading aloud is usually found to be impaired in these patients as the phonological output lexicon is part of the lexical route for reading. An impaired phonological output lexicon forces the reader to read via the sub-lexical route, making reading slower and inaccurate (as all words are read as new words) (Ellis and Young 1988; Biran and Friedmann 2005; Friedmann et al., 2013; Dotan and Friedmann 2015). Howard and Gatehouse (2006) found that patients exhibiting impairment in the phonological output lexicon produced many phonological paraphasias on a naming task (producing a word similar in sound to the target word). These patients produced semantic paraphasias, but at a significantly lower rate than the phonological paraphasias; Howard and Gatehouse attributed this to the fact that if access to the correct phonological output is blocked, the system may try another, semantically related word. Biran and Friedmann (2005) reported a frequency effect (frequent words were more likely to be retrieved correctly). They also found that the patients' pattern of errors indicated there were two different processes happening simultaneously--access to metrical information and segmental information, which are later merged into the word form--and that each one of these processes can be impaired independently.

Friedmann et al., (2013) point to ways in which it is possible to distinguish between impairment in the semantic lexicon and impairment in the phonological output lexicon: if the impairment is in the semantic lexicon and not in the phonological lexicon, word comprehension will be impaired, no phonological errors will be seen and word cueing strategies will help in lexical retrieval. In the case of impairment in the phonological output lexicon, word comprehension will be intact, many phonological errors will be seen in speech

production and treatment that focuses on the phonemes in the word will be effective (Nickles, 2002).

Ellis et al., (1992) point out that there is another possible deficit in the relationship between the semantic lexicon and the phonological lexicon and that the connection between them could be impaired while each of the two lexicons could be spared. The expectation is that a deficit in the connection between the lexicons will manifest itself in semantic and phonological paraphasias, good comprehension of pictures and words, and good reading and repetition of non-words. The difference between impairment in this location compared to one in the semantic lexicon itself is that here the subject most probably is able to understand auditory stimuli and written stimuli but has trouble producing words. This moreover differs from impairment in the phonological output lexicon in that the subject may still be able to read using the Lexical route and so reading abilities should be intact. Friedmann et al (2013) and Ellis et al (1992) cite the case of the patient Johann Voit, described by Garshey and discussed by Wernicke, 1886 who exhibited these very symptoms.

The final component of the lexical retrieval model that may be impaired is the phonological output buffer. The phonological output buffer is a phonological short term component that is closely related to phonological short term memory (Jacquemot & Scott 2006). Since this is the last stage of the model, comprehension is relatively spared. Nickles (1997) found that subjects with impairment here usually have no problems in comprehension of pictures, written words or auditory input. The most prominent difficulties these subjects will probably show will be in reading and repetition of non-words (Friedmann et al., 2013). Previous studies examining the phonological output buffer have found a similarity effect (Jacquemot & Scott 2006), a syllable frequency effect and a length effect (Dotan and Friedmann, 2015).

3.5 Summary

The Lexical retrieval model and the Dual route to reading model have shared components and are both a result of extensive research in aphasia and developmental dyslexia. Each component of the Lexical retrieval model and each of its connections to the other components of the model may be independently impaired. Each component corresponds to different patterns of impairment and so error analysis should be able to predict the probable location of impairment. The evidence cited for this view of lexical semantics and the written word has come from work on language impairment resulting from different types of brain damage. The following section will look at what previous research using these same tasks has found in children and adolescents with ASD.

Table 1. Summary: location of impairment and symptoms

Location of Impairment Symptoms

	Affected	Not affected
Conceptual System	Lexical retrieval problems, significant problems in comprehension, reading and writing, auditory processing and nonverbal situations	No phonological errors
Semantic lexicon	Word retrieval, reading, auditory comprehension, semantic paraphasias. Might show an imagenability effect, category specific impairments, and trouble in distinguishing between basic-level items inside the impaired category	Do well on picture tasks No phonological errors
Phonological output lexicon	Impairment mainly in production, reading via the sub-lexical route (slow and reading words like they were new), phonological paraphasias, and a frequency effect	Good conceptual and verbal comprehension, good silent reading comprehension and good auditory comprehension
Connection between semantic lexicon and the phonological output lexicon	Semantic and phonological paraphasias, has trouble producing words	Good comprehension of pictures and words, and good reading and repetition of non-words. Able to understand auditory stimuli and written stimuli. May still be able to read using the lexical route and so reading abilities should be intact
Phonological output buffer	Problems in reading and repetition of non-words, similarity effect, syllable frequency effect and a length effect	Comprehension is relatively spared

4. Previous studies on semantics in autism

One of the linguistic domains that has not received much research focus in ASD until recently is semantics. General reviews on language abilities in ASD have emphasized the great heterogeneity displayed in this population (Boucher, 2012; Eigsti et al., 2011; Groen et al., 2008; Kim et al., 2014; Kwok et al., 2015; Sterponi & Kirby, 2015; Surian & Siegal, 2008; Tager-Flusberg, 2005; Tager-Flusberg, 2005; Wilkinson, 1998). Lexical semantic abilities are no exception.

4.1 Semantic theories

One of the challenges involved in linguistic research on children with autism is accounting for the heterogeneity in language profiles. This has led to a concentration on the description of surface features, and is the reason for the difficulty surrounding efforts to identify and characterize the location of impairment.

Tager-Flusberg (1986) reviewed studies assessing language in children with autism and proposed the Semantic Deficit Hypothesis. Having found, on the one hand, studies that concluded that children with autism didn't use meaning to facilitate memory, learning or comprehension, and, on the other hand, studies that showed that children with autism can represent, organize and encode meaning effectively, she hypothesized that children with autism have a deficit in using semantic information (categories, word relations etc) and in the retrieval of stored information (picture naming, word finding etc). According to this hypothesis, not being able to restore semantic information (understand word meaning and be able to make useful word relations) will cause problems in the acquisition of all other linguistic areas, grammar in particular. Since 1986, the Semantic Deficit Hypothesis has been cast aside and more modern theories of executive functions have taken its place claiming that the semantic problems that are sometimes seen in children with autism are a result of

problems in integrating complex information, of weak central coherence (Frith, 1989; Frith & Happe, 1994) or deficits in executive functions (Griffith et al., 1999; Liss et al., 2001). Although the hypothesis itself has not been referred to in recent years, the results of recent studies continue to show the ambiguous pattern that Tager-Flusberg referred to – some children with autism performing at age levels, while others appearing to be impaired in their semantic abilities.

Another hypothesis that set out to explain lexical semantic abilities in children with autism is Naigles (2002) 'Form is easy, meaning is hard hypothesis'. Naigles focused on the acquisition of lexical semantics and argued that in order to acquire correct lexical meaning one has to understand the available social cues, context and input. Since children with autism display vast deficits in the area of social understanding, according to this theory, acquiring meaning would be very difficult. On the other hand, the aspects of language that don't require meaning, but only rules (such as grammar), would be acquired more efficiently.

Characterizing lexical knowledge in children with ASD means, of course, having a theory about lexical knowledge and how it is organized and used in typically developing (TD) children. Our study explicitly aims to look at lexical knowledge in children with ASD within the vantage point of a widely accepted model of lexical retrieval (which has received considerable empirical support from studies on aphasia, dyslexia and individuals with TD) which makes it possible to detail various loci of impairment.

4.2 Review of previous studies

The following section is a review of previous studies that have tested or reviewed lexical knowledge and the way it is used, in children with ASD. We included only articles that were related to lexical semantics and were published in

English. The number of studies found was relatively small compared to other areas of linguistic functioning in children with autism. We included studies with participants aged 2 (before this age autism diagnosis is rarely found and no studies were found with younger participants) up to age 23 (most studies assessing adolescents included participants up to age 23; studies with participants older than 23 years were considered adults). Only studies including (monolingual) children whose diagnosis at the time of assessment used "gold standard" diagnostic criteria (such as DSM-IV/V, ADOS and ADI-R) were included. Studies of so-called "optimal outcome" children and of children described as having "autistic traits," but who had no formal diagnosis, were not included. Most studies which adhered to our search criteria were conducted prior to publication of the DSM-V and the new terminology it entails; we included studies with participants labelled with all subtypes of autism diagnosis (HFA, LFA, Pervasive developmental disorder not otherwise specified - PDD-NOS, Asperger's Syndrome and autism) in order to see if diverging results between studies might be related to particular subtype.

Seventy- three studies were found to match the proposed criteria, of which twelve were general literature reviews on language and ASD (one of which was from a PhD dissertation). The remaining studies reported original data (including four PhD dissertations). For these studies reporting empirical results, we considered the following: (1) number of participants with autism, (2) mean age and range of participants with autism, (3) initial diagnosis of participants with autism, (4) method of diagnosis confirmation, (5) background measures provided, (6) tasks used, (7) centrality of semantics data in the study, (8) control group characteristics, (9) whether individuals with autism were found to have impaired or spared lexical semantic skills,

finally, (10) what the results say about the localization of impaired/spared components of the lexical retrieval model.

4.2.1 Centrality of investigation of lexical semantics

Beginning with the 12 literature reviews which corresponded to our search criteria (one of which was part of a PhD dissertation), only 2 were semantically centred (Arunachalam & Luyster, 2015; Naigles & Tek, 2017), however, neither of these directly and systematically examined lexical knowledge and its use in children with ASD. Arunachalam & Luyster (2015) reviewed what is known about the cognitive processes which underlie the acquisition of lexical knowledge in autism. Naigles & Tek (2017) reviewed evidence in favour of the hypothesis that "Form is easy, Meaning is hard," that meaning, broadly defined to encompass pragmatics and lexical semantics, is disproportionately impaired in ASD, compared to form, encompassing syntactic knowledge. They referred to data of children in preschool acquiring lexical semantics and note that the studies they found pointed to the fact that lexical learning was linked to social behaviour and so linguistic problems were linked to social competence. Arunachalam & Luyster, 2015, and Naigles & Tek, 2017, focused on how vocabulary is acquired (e.g. is there a shape bias?) and on which extra-linguistic processes might have an impact on word learning in children with ASD. Seven out of the twelve reviews reviewed studies on language abilities in children in autism with regard to a particular theory of autism, hence interpreting semantic abilities as part of a bigger linguistic deficit that is argued to be the result of various over-arching explanations ("Thinking in pictures" in Kunda & Goel, 2011; socio-affective and socio-cognitive (ToM - Theory of Mind) impairments in Boucher, 2003; Brook & Bowler, 1992; Surian & Siegal, 2008; Central Coherence theory in Noens & van Berckelaer-Onnes, 2005; neuroanatomical differences in Oxman &

Konstantareas, 1981; and long-term declarative memory in Boucher et al., 2008). Tager-Flusberg (1981) pointed out the lack of systematic research on semantics in autism compared to that found on children with Specific Language Impairment. She also noted that children with autism seem to do well on the PPVT (Peabody Picture Vocabulary Test), but have trouble with more complex tasks. Manookin (2004) examined studies of children with autism that focused on quantifiers and the difficulties that an impairment in acquiring them could pose for language and semantics. Magiati et al., (2014)'s review of longitudinal studies focusing on long-term outcomes in adults and adolescents with autism found that lexical semantics was one of the early language abilities, which, along with IQ, were the best predictors of later daily functioning.

Turning now to the 61 empirical studies matching our inclusion criteria, roughly half of these (32/61) focused on lexical semantics, meaning the main experimental task and research question were semantic in nature, rather than lexical semantics being merely part of a more general question about language ability in ASD. A few of these studies (5/32) were studies testing brain functions using a semantic task such as semantic priming or semantic recall (Dunn & Bates, 2005; Fiebelkorn et al., 2013; Knaus et al., 2008; Lo et al., 2013; McCleery et al., 2010). The other empirical studies matching our inclusion criteria (23/61) included semantic measures as part of a bigger linguistic study whose main focus was on another area (executive functions, grammar, word learning in social context or reading abilities). In these studies, lexical semantics measures were often used as a baseline measure for matching between groups or as part of the background measures describing the ASD group. The remaining six (6/61) were studies assessing language acquisition and word learning.

4.2.2 Characteristics of participants with ASD as found in previous studies

Although our review included all studies investigating lexical semantics in children with ASD (age 2 to 23), the majority of published articles were based on participants whose mean age was over 10 years old.

Out of the 61 research articles matching our criteria, age ranges (when mentioned; 11 did not supply this information) varied considerably. Only a third of these (21/61) involved studies in which the age range was less than five years (the age difference between the youngest participant and the oldest participant was less than five years). Many studies (27/61) had a participant age range of over five years, including some with a very wide age span of over 10 years. However, many of these latter did not include any participants under age ten (for example, Knaus et al., 2008, where the age range was 11– 19 years; Naigles et al., 2013, where the age range was 9– 17 years); it could be argued that although language still develops and evolves in these ages, the differences between participants based on age alone would be relatively smaller compared to studies that had a wide age range and children who were in the early stages of linguistic development and so the differences between the different linguistic abilities would be extremely different (for example, Paynter & Peterson, 2010, where the age range was 4– 13 years; Hartley & Allen, 2014, where the age range was 4– 16 years). The remaining two studies split the participants into two age groups and reported their findings accordingly.

In most studies the autism diagnosis was confirmed using one of the following tools: The Autism Diagnostic Interview-Revised (ADI-R), The Autism Diagnostic Observation Schedule (, ADOS), Diagnostic and Statistical Manual of Mental Disorders (DSM) or The International Classification of Diseases (ICD) based diagnosis procedures, The Childhood Autism Rating Scale (CARS), Social Communication Questionnaire (SCQ), Vineland Adaptive Behaviour Scales,

Modified Checklist for Autism in Toddlers (M-CHAT), Diagnostic Interview for Social and Communication Disorders (DISCO), The Griffiths Mental Development Scales, and the Gilliam Autism Rating Scale (GARS). The wide range of tools used from study to study to confirm the participants diagnosis make it hard to reach conclusions as each looks at autistic symptomology a little differently. We sought to determine whether diagnostic differences were an important contributor to the conclusion that lexical semantics in children with autism was impaired or not. Out of the 61 research studies, only 3 included children with Low Functioning Autism (LFA), defined as low verbal and nonverbal scores. The participants in most of the studies had been diagnosed with either Autism Spectrum Disorder or High Functioning Autism (HFA), defined by normal general IQ scores, age-equivalent verbal scores, normal nonverbal scores or all three.

4.2.3 Assessment of lexical semantics and study results

As the topic of our study concerns access and structure of lexical semantic knowledge in children with autism, we will not report here on tasks testing word learning (n=6). These tasks test different mechanisms in an attempt to chart growth curves over time or the number of mappings needed to learn words. Although these considerations do have a direct impact on lexical semantic knowledge, the focus of our study is not how lexical knowledge is acquired (see Naigles & Tek, 2017 for a review on vocabulary acquisition studies), but rather what aspects of already acquired lexical knowledge and use are impaired/spared. Studies reporting results which address this question have used a wide variety of tasks to test lexical semantics which differ according to which aspects of lexical semantics were targeted: (1) receptive vocabulary, (2) expressive vocabulary, (3) both expressive and receptive skills, (4) priming, (5) categorization and sorting, and (6) fluency. For each of these categories,

we looked at the specific tasks used and whether or not the participants with autism performed differently from controls (and how these controls were matched) and/or from task norms.

4.2.3.1 Receptive vocabulary

Receptive vocabulary refers to words, objects or pictures that a person can comprehend and respond to in any way, verbal or nonverbal. Receptive vocabulary tasks were the most frequently used tasks in the studies under review. A majority of these studies found the ASD group as having significantly lower scores than the control groups and no variable was found as having a big influence on the results.

More than half of the research studies (35/61) used the PPVT (Peabody Picture Vocabulary Test), one of its adapted versions or the BPV (British Picture Vocabulary). These studies used these tasks as background measures and reported only global scores (individual, or only group means, depending on the study), except for one case study (Boser et al., 2002), which also looked at error patterns and found that the subject often pointed to the lower left picture when he was unsure of the target.

Out of the 35 studies using one of the versions of the PPVT, the group of children with autism was found to have lower scores than the control group or the task norms for their age group in 24 of them. In some (8/24), the score on this specific task was used to match the group of children with autism to a group of typically developing children, which in all eight studies were thus significantly younger in age. Eleven studies out of the 35 studies that used one of the versions of the PPVT, found that the performance of the group of children with autism was age-matched. In all of these 11 studies, the score on the PPVT was used as matching criteria between the

group of children with autism and a group of typically developing children of the same age, in some, this score was also the inclusion criteria for the study.

One difference between the studies that found ASD participants to be at age level versus those that found them to be below age level was the age of the participants. In most of the former studies, the children with ASD were older than age ten (the youngest participants in this group of studies were 8 years old). All the participants in these studies were diagnosed as either HFA or ASD, and TD controls were matched on age, verbal IQ, nonverbal IQ, and in some, reading scores. In other words, these children seemed to have no language impairment. On the other hand, studies that found the ASD group to perform significantly lower than controls tended to have younger participants, aged between 5-10 years; in addition, these studies included participants diagnosed as having LFA, HFA and ASD, and in some there was also an explicit diagnosis of language impairment or learning disabilities.

Three non-standardized, experimental tasks testing word-picture matching were used to assess receptive vocabulary: Four studies used a word – picture matching task (Boser et al., 2002 - auditory word-to-picture-matching; Norbury, 2005 ambiguous words - picture matching; McCleery et al., 2010 semantically matching and mismatching picture–word and picture–environmental sound pairs; Venker et al., 2016 - Looking while listening task). Out of these four studies testing word-picture matching, two found the group of children with autism to obtain significantly lower scores compared to the control group in the study (Boser et al., 2002: task norms; Norbury, 2005: control group matched on nonverbal score and age). Norbury (2005) further categorized children with autism and language impairments (ASD-LI) and children with autism without language impairments (ASD- LN). The group that was found as having significantly lower scores compared to controls was the ASD-LI

group. In the study done by McCleery et al.,(2010) the group of children with autism was found as having the same scores compared to the control group (who were matched on nonverbal score, verbal score and age) but differences were found in the brain waves that were analysed. The study by Venker et al.,(2016) that compared the results of children with autism on the Looking while Listening task to parental reports of speech found that the children with autism understood significantly more words than their parents had reported and no significant differences were found compared to previous studies with typically developing children.

Groen et al., (2010) tested children with HFA on a sentence judgment task using pseudo-words and Knaus et al., (2008) tested children with autism on a reading version of a response-naming task. The focus of both of these studies was brain activation of language areas in children with autism during the completion of a semantic task. Both studies found the scores of children with autism to be equivalent to those of control children (matched on verbal, nonverbal and age in Groen et al., 2010, and age-matched in Knaus et al., 2008), but differences in brain activation were found, which the authors interpreted to mean that although the end results and functions of children with ASD were similar to TD's, the underlying mechanisms used to achieve the same results might be different as indicated by the different brain waves.

In summary, it seems that although the results of the different receptive task are mixed in their findings, age and language impairment are influential on the outcome.

4.2.3.2 Expressive vocabulary

Expressive vocabulary refers to words that a person can produce. Testing expressive vocabulary requires the participants to respond and so these tasks are

sometimes challenging when used in research in children with autism as it's not always clear if errors are a result of poor expressive abilities or of problems with comprehending the task demands. In the current review the most common method found for testing Expressive vocabulary was different versions of a picture naming task (the Expressive Vocabulary Test (EVT), Boston Naming test, The Renfrew Word-Finding test and an experimental task testing picture naming of low frequency nouns). In most studies the ASD group was found to have lower scores than controls and in the studies that reported an error analysis different patterns were observed between groups.

Three studies used the Expressive Vocabulary Test -EVT (Battagalia, 2012; Condouris et al., 2003; McGregor et al., 2012). In all three studies the group of children with autism was found to have lower scores compared to controls of the same chronological age or to the task norms. In the study by McGregor et al., (2012) a distinction was made between children with autism with and without language impairment, children with autism and language impairments were those who had scaled scores of under 8 on the syntactic subtests of the CELF4. The group of children with autism and no language impairment ASD-LN was found as matching TD children of the same age on this task. The same result was obtained for the second task used in this study, an auditory word association task, children with autism and language impairment ASD-LI were found to have lower scores than controls and children with autism without language impairment were found to be control matched.

Different picture naming tasks were used in four more studies (Boston Naming Test - Löfkvist et al., 2014; Renfrew Word-Finding test – Boucher, 1988; Vogindroukas et al., 2003; Picture naming of low frequency nouns - Walenski et al., 2008). Two studies found the scores of the group of children with autism to be age

matched to controls. In Boucher, 1988, this score was used to match the autism group with an age matched TD group of children. In the study by Walenski et al., (2008) the scores of the children with autism were higher than those of the controls who were boys and matched to the scores of TD girls. In both of these studies an error analysis was not provided. The two remaining studies both found the group of children with autism to have scores significantly lower than the control group. Löfkvist et al., (2014) did an in depth analysis of the errors made by the autism group and found them to be different than those of the other groups. They found many semantically irrelevant answers, perseverations and answers that, although they were semantically relevant, were very different than the kind of errors made in the other groups tested (age matched TD children, age matched children with language impairment, age-matched children with cochlear implants). Vogindroukas et al., (2003) compared the group of children with autism to a group of children of the same age with mild learning disabilities. No differences between groups were found and the two groups were found to use the same strategies when producing an incorrect response. Error analysis revealed that the children with autism produced many global and semantic paraphasias, which were observed at significantly lower rates in the group of children with mild learning disabilities.

In summary, no single variable (age, ASD subtype, control group or task type) was found to significantly affect the results, which were mixed in nature.

4.2.3.3 Tasks testing expressive and receptive vocabulary

Several studies reported standardized composite language scores which were based on both expressive and receptive vocabulary measures (the MacArthur-Bates Communicative Development Inventories – CDI; the Evaluation of Language Fundamentals- CELF; and the Reynell Developmental Language Scales NRDLS).

These scores were generally reported as background measures and/or for matching children with ASD to TD controls.

Studies reporting scores from the CDI (n = 7), a parental survey that assesses the words that a child produces and understands found mixed results. In all seven studies, the mean age of the participants in the autism group, who had a diagnosis of ASD, was under age five. In most studies (5/7), the children with autism were found to have lower scores than expected from their age group. In some (2/5) studies the autism group were found to have age matched scores and in some (3/5) studies the score on this task was used to match the control participants who were younger in age.

Studies reporting results from the CELF (n = 13), a battery of tests evaluating receptive and expressive language measures, showed different results; in all 13 studies, the ASD group were diagnosed as having ASD or HFA (HFA was defined as having no language disabilities in all studies). In some (4/15), children with ASD were found to have age-matched scores (of these two were HFA) and in other studies (9/15) the ASD group (of these two were HFA) had significantly lower scores compared to TD children of the same age. In most studies, CELF scores were the matching criterion between the ASD group and the controls.

Another omnibus battery evaluating both receptive and expressive language, the Reynell Developmental Language Scales (NRDLS), was used by Miniscalco et al., (2012) as a background measure (with only global scores reported). The autism group in this study, which consisted of children diagnosed with ASD who were below age five, was found to have significantly lower scores than the task norms for their age group.

Results across all tasks were mixed, some finding ASD participants to be control matched in their abilities, although the majority of studies found the ASD

groups to have significantly lower scores than the task norms or control groups despite having different diagnosis (ASD, HFA) and different age groups.

4.2.3.4 Priming tasks

Priming is an implicit memory effect in which exposure to one stimulus influences the response to another. In the studies surveyed here, four different priming tasks were used: (1) cross-model semantic priming, (2) lexical decision with semantic priming, (3) individualized semantic priming, and (4) reading priming. The results found were mixed, although most studies found that access to semantics seems to be matched to controls while processing and complex retrieval seem to be different.

Three studies used a cross-model semantic priming task. Harper-Hill et al., (2014 a, b) found children with HFA (all of whom were over age ten) that were matched to a control group of TD children on age, CELF4 core language scores, PPVT scores, Raven's progressive matrices (RPM) scores and the Woodcock Johnson reading diagnostic battery scores to be as fast and accurate as the TD children and that priming effects didn't seem to differ between groups. Henderson et al., (2011) compared a group of children with autism (mean group age over ten years, diagnosed as ASD , four of these were categorized as having Asperger's syndrome) to a group of TD controls matched on age, receptive vocabulary, listening recall, nonword repetition and reading and found that children with autism seemed to be able to access semantic information early in the time course tested with no significant difference with controls, but when tested again over a week later, many errors occurred, suggesting that this group of children with autism had intact access to semantics but problems with processing or retrieving information over time.

Two studies used a lexical decision with semantic priming task, and came to different conclusions, although it is unclear what influenced the different results as

these studies had different age and autism subtypes. Haibeg et al., (2015) tested children with ASD between the age of five and ten, SLI and TD children matched on age and receptive vocabulary (PPVT) and found that children across all groups were more accurate when responding to words from high semantic networks than low semantic networks and responded to words better than pseudo-words. Their conclusions were that semantic knowledge is organized in a similar fashion in children with autism, typically developing children and children with SLI. On the other hand, Kamio et al., (2007) tested children with HFA (mean group age over ten years old) that failed to show the same priming effects as typically developing children who were matched on age, IQ score (> 70) and reading scores.

Battagalia (2012) used an individualised semantic priming task and found that children with autism (mean group age over ten, diagnosed as ASD) seemed to exhibit the same reaction time as their peers but that not all priming conditions had the same effects as they did on the typically developing groups, one group matched on chronological age and the other matched on verbal score and were 4-5 years younger than the autism participants.

Hala et al., (2007) used a reading priming task and found that although priming had a positive effect on reading of homographs in the autism group (mean group age over ten, diagnosed as ASD), the effect was not long lasting and wasn't persistent when children were tested on reading the same homographs a second time.

Although all the tasks were semantic priming tasks, they were different in their specific characteristics, and, moreover, the characteristics of the children with ASD varied from study to study.

4.2.3.5 Categorization and sorting tasks

Categorization is the process in which ideas and objects are recognized, differentiated and understood. Categorization tasks aim to reveal the underlying structure of semantic knowledge. In the studies reviewed here, five types of categorization tasks were found: (1) auditory classification, (2) categorical induction task, (3) visual categorization, (4) sorting task and (5) the Semantic Feature Test. Some studies found no differences compared to controls, while others found very different error patterns and reaction times.

Some studies reporting on auditory classification tasks found that children with ASD had slower reaction times than controls (matched on nonverbal score and age in Dunn et al., 1999; on verbal scores, nonverbal scores and age in Gastgeb et al., 2006). Dunn et al., (1999) also found the children with autism to be less accurate than the control group although not significantly. Gastgeb et al., (2006) found that typicality affected the reaction time of children with autism (ages 9 to 12) characterized as being HFA, but not of controls, and that this effect was not observed in the group of adolescents with autism (ages 13 to 16) who performed at same levels and reaction times as the group of controls. Another study using an auditory classification task with children with ASD matched to TD children on nonverbal score and age, Dunn and Bates (2005), found no significant inter-group differences in accuracy or reaction times, but brain activation patterns were different in the autism group.

A categorical induction task was used in two studies. Naigles et al., (2013) found that both the TD group and the autism group, who were matched on age and nonverbal score, demonstrated some knowledge of category structure by extending at above-chance levels meaning both groups were able to observe specific properties for some exemplars of a category and then transfer these to new items; however, the TD

group extended more consistently than the group with autism. Tager-Flusberg (1985) had previously found that the same patterns of overextension and under-extension errors that were related to a prototype representation of the underlying concepts were used in three different groups of children (children with autism, with mental retardation and TD children, matched on receptive vocabulary score (PPVT), TD children were significantly younger in age) and no significant inter-group differences were found on accuracy scores.

Fiebelkorn et al., (2013) used a visual categorization task and similar to the results found in Dunn and Bates (2005), no significant differences were found in the children's performance across the different groups (TD children matched on age, verbal score and nonverbal score and children with HFA), but differences were observed in the brain activation to the stimuli. Ropar & Peebles (2007) used a sorting task and found that the group of children with ASD were more likely to sort objects according to concrete criteria and had trouble with abstract concepts compared to TD children matched on age and verbal score (BPVS). Finally, Löfkvist et al., (2014) used the Semantic Features Test and found that the children with autism had lower accuracy scores than the other groups tested, which included children with cochlear implants, children with SLI and TD children matched on age and a nonverbal score (Raven's Progressive Matrices, RPM).

It appears that although some studies found the ASD groups to be just as accurate as controls in the number of correct responses but with different error patterns and strategies, others found both their scores and error patterns to be different from those found for controls. A possible explanation is the fact that all studies that found no differences had children with ASD that were HFA or had normal background language measures, meaning they had no linguistic impairment.

4.2.3.6 Fluency tasks

Fluency tasks are tasks in which participants have to say as many words as possible, in a time frame or freely, usually as a response to a specific cue (ex. animals). These kind of tasks yield a score for the number of correct answers, but also the number of repetitions, the number and length of word clusters (number of words generated from the same subcategory, ex. farm animals.) and number of switches (the ability to effectively change to another subcategory, ex. pets). Three studies reported results of a fluency task, and these went in different directions. Begeer et al., (2013) and Dunn et al., (1996) found that the group of children and adolescents with autism produced the same number of total correct responses as a group of TD children matched on age and receptive vocabulary (PPVT > 80) but the autism group switched less frequently and had larger clusters (indicating that they retrieved more items from a specific subcategory). Turner (1999) tested children with HFA (mean group age five years) on three different fluency tasks: letter fluency, category fluency, and object uses fluency. In all three tasks the children with autism produced significantly fewer words, had reduced clustering and less switching than the control group of TD children matched on age, verbal score and nonverbal score. In the study by Begeer et al., (2013) the ASD participants had a score on the PPVT > 80 but no other ASD characteristics were given, but they were older (mean group age of over 10) than the group of ASD children in Dunn et al., (1996) who had a mean age of 6.2 years. In the study by Turner (1999), the children we referred to were a group of HFA children with a verbal IQ score of >76 on the Wechsler Intelligence Scales (WISC) and this score might explain the differences between studies. Also, Begeer et al., (2013) in their discussion point to the fact that scoring was done differently than the study by Turner (1999) and this too might influence results.

4.2.3.7 Word Recall tasks

Word Recall tasks are aimed at assessing memory functions, the way information is stored and the ways that different cues can aid in the retrieval of information. Four studies used different recall tasks and were mixed in their conclusions.

Tager-Flusberg (1991) tested children with ASD (*n*= 15; mean age= 13.5 years) on a semantic/phonological word recall task and on a cued word recall task. The control groups in this study included a group of age-matched children with intellectual disability and a group of TD children, matched to the ASD group for a verbal score (PPVT) and a nonverbal score (RPM), that were significantly younger in age (mean age = 4.7). Participants were asked to recall two lists of words, related and unrelated. On the recall of the unrelated list, no differences between groups were found, but on the recall of the related items, the ASD scores were lower than those of the controls. In the control group, recall was better on the related word list, but in the ASD group correct recall was the same for both lists. Moreover, the ASD group was found to produce nearly three times more incorrect words than either of the other groups. The second task in this study was a cued recall task wherein participants heard word lists and were given cues (rhyme / category membership statement) to the words they hadn't recalled. No difference between groups was found in recall before or after the cue. The author concluded that the results from the first experiment reinforce the notion that children with ASD have specific difficulties in processing semantic, syntactic and other structured verbal information and that the results of the second study suggest that the deficit is a result of failing to use linguistic information efficiently in order to retrieve stored information. Lopez (2001) replicated this study, but with longer word lists, to increase statistical power. Her study included children with HFA (*n*=15; mean age=13.1 years) and an age-matched control group. Although

both groups performed better on the related than unrelated condition, the ASD group had significantly lower scores than controls, and it was therefore concluded that participants with ASD were able to integrate words on the basis of meaning.

Whitehouse et al., (2007) compared children with HFA (*n*=20; mean age= 10 years) to two control groups, a group of TD age-matched children and a group of TDs matched on a verbal score (PPVT), a nonverbal score (RPM) and a reading score (Castles Nonword Test), who were significantly younger in age. No differences were found between the ASD group to the two control groups in either condition tested (phonological / semantic).

Finally, Ramondo & Milech (1984) compared children diagnosed with infantile autism (n=12; mean age= 13.5), a group of children with intellectual disability and a group of TD children matched on digit span (WISC), PPVT and MLU, who were five years younger. All children completed an auditory word recall task with two conditions; in one the participants were presented with random strings of words and in the second the same words were used in sentences were semantic relatedness was a key component. In all groups recall was better when there was semantic relatedness and grammatically well formed sentences, although the participants with ASD performed significantly lower than both other groups on all conditions.

In summary, only one study found the ASD group to have performance like age-matched TDs, and in this case the ASD group had no language delay or intellectual disability. The conclusion from the linguistic measures presented in the three other studies is that the group of children with ASD had language impairment. In these studies, it seems that the most influential variable was participant

characteristics and whether or not they had independently measured language impairment.

4.2.4 Do children with ASD display impaired lexical semantics?

Across all 61 studies surveyed here, we found entirely mixed results for lexical semantic assessment. Putting aside studies for which no clear lexical semantic results were reported (because these scores were not explicitly reported, but only parallel on-line measures obtained while the lexical semantic task was being performed; *n*=4), three basic scenarios were observed: (1) participants with autism displayed impaired lexical semantics (either because they had significantly lower scores compared to controls and / or task norms or because their performance was like that of younger controls) on all measures tested, (2) participants with autism were found to be unimpaired and thus matched to age-controls and (3) participants with autism were found to be impaired only on some measures tested.

Roughly half of the studies (31/61) found that participants with autism had significantly lower scores than control children, variously matched on age, nonverbal level, and/or verbal level, or than age norms on all measures reported. The diagnosis of participants with autism in these studies consisted of all subtypes of autism – PDD-NOS, autism, Asperger's syndrome, autism and learning disabilities, autism and language impairment, HFA and LFA. In all 31 studies, the autism group performed significantly lower than the control group on the experimental tasks, and, where reported, linguistic strategies and error types were different from those of the control group. These 31 studies included all task types and no unique characteristics were found aside from the fact that it seems that in many studies the ASD group also had language impairment (either diagnosed prior to the study or indicated by low scores on linguistic measures).

A sizable number of studies reviewed (26/61) found the autism group to be matched to controls in their semantic abilities. The control groups used in these studies matched the control groups to the autism group in different ways as previously described (age or age and different combinations of verbal / nonverbal scores). When taking into account the control groups used, the conclusion is that the participants with autism had no linguistic impairment, including no semantic impairment and so all their semantic measures were age equivalent. These studies included all subtypes of autism and all task types.

Four studies found that children with autism were only partially different than controls on the tasks tested, meaning that on some measures their scores were matched to the control group while on others they were significantly lower. Hani, (2015) tested a language-impaired ASD group matched to TD controls on age and NVIQ. The ASD group had significantly lower scores than the TD group on phonological awareness, a single word picture naming task, receptive vocabulary and on a word-learning task that required identifying a labelled object in a different colour after a long delay. Groups had similar scores on the word learning task. Lopez, (2001) and Lopez & Leekam, (2003) tested children with HFA and age-matched TD controls. The ASD group was able to use semantic category information to aid recall however had difficulties with a sentence processing task when using sentence context to disambiguate homographs. Tek et al., (2014) found that children with ASD who had higher verbal skills were comparable to TD children on most language measures, whereas the children with ASD who had low verbal skills had lower scores in most language measures.

In line with past reviews (Arunachalam & Luyster,2015; Naigles and Tek 2017; Tager-Flusberg, 1981), we were unable to find one single factor that influenced

the performance of children with ASD on lexical semantic tasks. The one variable that seemed to influence study results was whether participants with ASD had language impairment. In all studies in which this was the case, the ASD group were found to be impaired on lexical semantics compared to controls. However, this explanation is not sufficient; there were also studies with ASD participants without language impairment, who were matched to TD participants for age, nonverbal scores and IQ scores, who were also found to be impaired on lexical semantic tasks. In other words, there were children with ASD with language impairment and lexical semantic impairment, but also children with ASD with lexical semantic impairment, despite age-equivalent (general) language scores. The opposite was not found: no study reported language impaired children with ASD had had age-equivalent lexical semantic scores.

4.2.5 Can the locus of impairment in the Lexical retrieval model be identified?

The DSM-V places ASD inside the broader category of neurodevelopmental disorders. The implication of this is that we should be looking at brain areas and brain functions in order to establish an idea of where the impairment is located. When diagnosing patients with brain trauma or aphasia of different kinds, researchers tend to work their way by a certain model testing each part and thus reaching a firm conclusion regarding the impairment and its location in the brain. By doing this, treatment methods, both medical and behavioural have become much more effective.

Although extensive research in aphasia and developmental dyslexia (see Friedmann et al., 2013 and Friedmann and Coltheart, 2016 for an extensive review) has provided empirical support for the Lexical Retrieval Model and its predictions for the different repercussions of impairment at different locations (see Sections 2.2 and

2.3), these models have rarely been applied to other cognitive disorders (for SLI, see Martin et al., 1994). Studies that have been conducted with patients with aphasia with regard to the lexical retrieval model, look at the specific parts of the model, match a task testing each individual part and look at the individual components to try and predict how a certain impairment at a certain location would manifest itself and look closely at errors made and linguistic strategies used (see Section 3.4).

We set out to report the existing data on lexical semantic abilities in children with autism and to compare them to the Lexical Retrieval Model. No study provided an array of results relating to the different components of the lexical retrieval model or even to different linguistic domains, which would have given a global language profile for each of individuals tested. This basic short-coming, the lack of extensive research protocols that take into account all linguistic domains and that would thus allow for complete profiles of linguistic competence and, in particular, of the lexical semantic abilities of individuals with autism, is mentioned by several authors (ex. Tager-Flusberg, 1981; Naigles et al., 2017).

Without knowing a participant's abilities on all parts of the lexical retrieval model, it is very difficult to determine whether one or more parts of it are impaired/spared or if impairment is semantic in nature or related to other deficiencies. For example, Gastgeb et al., (2016) tested children and adolescents with HFA (IQ>80) on an experimental category verification task, in which the participant was asked to choose whether a certain picture was part of a category presented auditorily (he/she heard the word "cat" and had to decide if the picture on the screen belonged to this category), participants responded by pressing a true/false button. The autism group had significantly lower accuracy scores and higher reaction times than a control group of TD children matched on full scale IQ, verbal scores, nonverbal score and

age. The experimental protocols tested both the conceptual system and the semantic lexicon, since children had to recognize the objects being presented (visually and auditorily) and also had to understand the relationships between the two words (Were they related to the same category?), as well as to understand the instruction to press the correct button; children clearly had to also use their phonological input lexicon, as well as syntactic knowledge. Since these latter were not independently tested, we have no way of knowing if one of these could have affected the results. For example, a child with an impaired phonological input lexicon would have trouble understanding the auditory input and thus end up choosing incorrectly. This hypothesis, that the impairment is located in the phonological lexicon, could be verified by a low score on a naming task, together with numerous phonological errors. Moreover, the researchers themselves noted that memory deficits or problems processing visual stimuli could also result in similar behavioural patterns.

There were also studies which did use a wide variety of tasks that tested all the components of the lexical retrieval model, but which did not include an in-depth error analysis, making it impossible to pinpoint the source of deficits. For example, Henderson et al., (2011) tested children with ASD on a cross-model semantic priming task. They found that these children had intact access to semantic information early in the time course, but had many errors later in time. These children with ASD did not have language impairment and were matched to a group of TD children on age, receptive vocabulary, listening recall and nonword repetition. This study had several background measures (BPV- British Picture Vocabulary, BAS – British Ability Scales, listening recall, CNREP - Children's Test of Nonword Repetition, GNWRT- Graded Nonword Reading Test, NARA- Neale Analysis of Reading Ability) which, together with the experimental task, cover all of the components of the lexical

retrieval model. An error analysis of nonword repetition would have allowed us to see if there are problems in the phonological input or output lexicons (errors would include shifting of phonemes from different parts of the word or from previous words and stimuli). An error analysis of the picture tasks would have allowed us to see if the errors were semantic in nature. For example, if on the BPV a participant consistently pointed to one of the semantic distracters and not the target, this would be indicative of an impaired semantic lexicon. If, on the other hand, subjects consistently pointed to a phonological distracter, this would indicate that the phonological output lexicon is impaired. Finally, if answers were not related to a given stimuli, such as unrelated paraphasias (saying "carrot" in response to a picture of a car), it could have been concluded that there might be a problem with the conceptual system.

It seems that the general tendency in most existing studies has been to describe a very specific part of linguistic abilities in children with autism, even in the case of studies in which several background measures had been collected. The result is an in-depth analysis of only a very small part of the data collected.

4.3 Summary

Studies on lexical semantics in children with autism have yielded contradicting results. Our attempt to find an explanation for these contradictions by viewing previous studies in light of an explicit lexical retrieval model did not meet with success. In the 77 studies reviewed, it was impossible to determine the exact location of impairment in the Lexical retrieval model, due to incomplete information in each study. No single factor was found to affect lexical semantic abilities, although children with broader linguistic impairment generally, but not universally, also showed impaired lexical semantic abilities.

5. Conclusions and research questions

Previous studies on both lexical semantics and on reading in children with ASD have found contradicting results, with some ASD participants scoring at age equivalent levels while others were found to be impaired. No single variable was found to influence the results, but it seems that both for reading and lexical semantics abilities, syntactic abilities may play a role in understanding the degree of impairment.

Previous studies that have tested semantic abilities in children with ASD have for the most part been focused on a specific task or linguistic ability while providing very little data on the background features and other linguistic abilities of the children participating in the study. In many studies error analysis on the semantic tasks was very superficial, not enabling us to reach conclusions regarding the specific semantic impairment and its relation to other linguistic features of the participants.

Given the important role that lexical semantics plays in language assessment and the fact that many studies use lexical semantic scores as an indication for overall language abilities it is crucial that we truly understand the degree and nature of semantic impairment in children with ASD as well as how this impairment may be affecting other linguistic functions. We address this problem by using the Lexical retrieval model and the Dual route to reading model, for the first time with children with ASD. Our investigation is organized according to the following three research questions.

1. Is the semantic component impaired in children with ASD?

The first, and fundamental question is whether (some) children with ASD display impairment in the semantic component. If an impairment in the semantic component exists, it could be manifested as trouble accessing this component, deficits inside the component (choosing between close category items) or as a deficit

connecting the semantic component to other components in the model (e.g., conceptual, syntax, phonological output lexicon, orthographic input lexicon). If the semantic component is not impaired, we would expect children with ASD to perform at an age equivalent level on tasks testing the semantic component (those requiring either access to this component, internal function of this component, or links between this component and other components).

2. Does the explicitness/implicitness of semantic tasks influence performance?

The second research question is related to how lexical semantics is tested, and whether performance on such tasks improves if they include explicit instruction to use semantic knowledge. One of the key problems of children with ASD is their trouble to reach conclusions based on other's actions. In my work with ASD children, I encountered many who when given an explicit task demand (such as "you have to think of the meaning of this word and then say it out load") displayed better cooperation and motivation to complete tasks. We therefore sought to determine if explicit reference to word meaning improved performance on tasks requiring lexical semantic knowledge. If such an influence exists, we would expect to see significant differences between tasks testing explicit access versus tasks testing implicit access in favor of explicit tasks (as these include direct instruction).

3. Does impairment in the semantic component affect syntactic performance, or can the syntactic component be impaired independently from the semantic component?

Finally, our third research question concerns the relationship between impairment in lexical semantics and impairment in syntax, and thus directly addresses the question of whether lexical semantic performance is an accurate indication of

overall language ability. For example, since sentences are made up of words, it could be imagined that any syntactic impairment is simply due to impaired lexical semantics. Can impaired syntax in ASD be argued to be a result of impaired lexical semantics, or can syntax be impaired independently of lexical semantics? Impairment in the semantic component would result in low scores on semantic tasks, obviously. If this impairment is affecting comprehension, for example, we would expect to see comprehension difficulties on all sentence structures (simple and complex sentences), as both require lexical semantic knowledge. On the other hand, if there is a syntactic deficit that is unrelated to semantics, then we would expect to see a specific pattern of syntactic performance, with good comprehension and production of syntactically simple sentences, but profound difficulties in the comprehension and production of syntactically complex sentences, alongside good performance on semantic tasks, the pattern that is observed, for example, in children with SLI who have impaired syntax. We would expect to find the well-known dissociations observed between less complex and more complex structures (e.g. subject relatives versus object relatives, or sentences without verb movement versus those with such movement).

Based on past studies and the wide use of lexical semantics as a proxy for language, we expect to see some degree of a connection between semantic abilities and other linguistic abilities. The Lexical retrieval model and The Dual route to reading model have successfully been used in past studies with other populations in order to pin point an exact location of impairment. These two models predict that four linguistic profiles may be found: (1) children who are TD age matched in their performance on all tasks (meaning they have no semantic or linguistic impairment), (2) children who have impaired performance on all tasks (meaning they have a semantic and a wider linguistic impairment), (3) children who have an intact semantic

component but impairments in other locations of the model, and (4) children who have an exclusive semantic impairment (meaning no other component is impaired except the semantic component).

The following chapters will make explicit how using the Lexical retrieval model and the Dual route to reading model will be used to explore language impairment in children with ASD. We begin by outlining the 16 tasks that were chosen for this research based on their ability to test the different components of the models and their ability (through performance and error analysis) to provide a wide and profound assessment of participants' linguistic abilities.

Method

6. General method

The aim of the current study was to explore the linguistic impairment seen in individuals with autism with special focus on lexical semantic abilities in order to determine whether semantic impairment exists, and, if so, what its exact location and manifestations are.

A mixed method approach was chosen in order to be able to analyze the findings both qualitatively and quantitatively. Several studies have found that children with ASD obtain age- equivalent scores, but differ either in errors patterns or in on-line measures. For example, four studies (see previous chapter for detailed description – Dunn & Bates, 2005; Fiebelkorn et al., 2013; Groen et al., 2010; Knaus et al., 2008) found no significant differences on the scores of the ASD group they tested compared to age-matched TD, but they did find significant differences and patterns in the brain waves of children with autism. Four more studies tested children with autism on different semantic tasks (Battagalia, 2012- semantic priming; Begeer et al., 2013 and Dunn et al., 1996 – fluency task; Vogindroukas et al., 2003- naming task) and all found them to perform quantitatively like controls, but not qualitatively, as error patterns and strategies were different.

Studies with children and adults with aphasia as well as studies with children and adults with dyslexia have used The Lexical retrieval model and The Dual route to reading model (respectively) in order to test all the components of the model and then single out the location of impairment based on scores on the different tasks as well as an in-depth error analysis that can differentiate between different types of impairment. As seen in Chapter 3, these models share several components and therefore a common model was devised especially for this study, as shown in Figure 3.

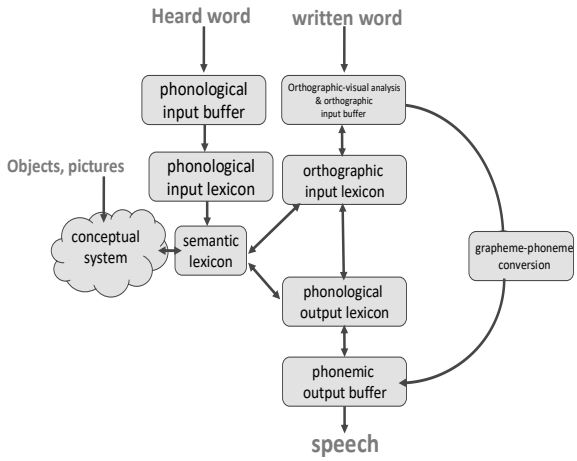


Figure 3. Lexical retrieval and Dual route shared model

Most linguistic tasks test more than one component, and therefore the tasks chosen for this study are somewhat overlapping in the components they test. Whenever possible, tasks that test only one component were chosen over others that test several components – but in many cases it was impossible to find a task that tested a single component. Although a task tested different components, by comparing the task with other tasks or by looking at the errors on the specific task, it was possible to differentiate the different impairment locations. For example, the word-picture matching task (see detailed description in Section 7.2.2) in which the participant is asked to read a word and point to a related picture, tests the conceptual system, the semantic lexicon, orthographic-visual analysis and orthographic input buffer, and the orthographic input lexicon. By comparing the results of this task to, on the one hand, the results of the Word-association task (Ma Kashur -Section 7.4.1) , which tests only the orthographic-visual analysis and orthographic input buffer and the orthographic input lexicon and, on the other hand, the results of one of the tasks testing the conceptual system (such as the Picture association task, Section 7.1.3), we can determine whether poor performance on this task was due to an impairment in the conceptual system, in the semantic lexicon or in reading related components. In order

to confirm this conclusion, an error analysis may confirm the nature and characteristics of the impairment.

Motivation for task completion and cooperation are problematic aspects of testing children with autism. It has been proposed in the past that testing children with computer-based tasks might heighten motivation for cooperation. Whenever possible, the tasks used were modified from their original versions to enable testing with the aid of a computer, hence making the task a "computer game".

6.1 Participants

6.1.1 Inclusion criteria and recruitment procedure

As described in the previous chapter, obtaining full diagnostic measures of participants with ASD is problematic in Israel; however, in order to be eligible for special education placement and rights, the law is very clear on the diagnostic procedures and so a child that is attending one of the special education programs, by default has a current diagnosis. For this reason I choose to recruit children from such programs. Israel has many bilingual children but since bilingual language acquisition of language varies considerably for a number of variables (including age, length and richness of language exposure and use), only monolingual Hebrew speaking children were included in this study.

Age was the third inclusion criterion. In Israel, children start school at the age of six years. Children aged eight years and older were chosen to participate so that testing would be done in a setting that is familiar to them (and thus not during their first year of school). Since past studies have shown an improvement with age of linguistic abilities in children with ASD (Anderson et al., 2007; Geurts & Embrechts, 2008), the aim was to include children with a wide age range. Another reason for including children who were at least eight years old was that the majority of these

children would already have acquired some reading skills making it possible to test more aspects of semantic functioning. Finally, only children who were diagnosed with ASD but no other condition (such as ADHD, ID, hearing impairment etc) as these would be variables that would be hard to account for. Children with all levels of functioning were included, HFA, ASD and LFA, unless they were unable to cooperate, in which case they were excluded from the sample.

The research plan was approved by the François Rabelais University, Tours, doctoral school, following which an ethics and research approval was granted by the research division of the Ministry of Education in Israel, which evaluated the entire research protocol. I then contacted five regional special education supervisors, who all agreed to participate in the project. From the special education supervisors I received the contact details of 20 schools; three were special education schools and 17 were regular schools having small special education classrooms. All three special education schools declined because they had too many other research projects already at the school. Out of the 17 schools with special education classrooms, 8 agreed to take part in the study. Each school had between two to six special education classes. A formal letter explaining the research aims and protocol was sent to the parents of all the children in these classes; parents had to sign a consent form enabling their child to participate in the research. 168 letters were sent to parents, less than 30% returned their consent (n = 43). Out of these, three children were not included in the analysis because they were unable to cooperate with the tasks and two more children stated that, although their parents signed the consent form, they were not interested in participating. One participant with LFA who was being homeschooled by his mother was recruited after his brother (diagnosed with HFA) brought home the research letter.

The control group of children recruited for this research was recruited from a regular school. A letter explaining the research aim had been sent to the parents of all the children in this classroom (*n* = 35); 25 agreed for their children to participate in the study. Out of these, eight had either ADHD or some other diagnosed learning disability and weren't included in the study.

6.1.2 Participant characteristics

6.1.2.1 Autism group

Thirty-eight children with autism participated in the current study, 34 boys and 4 girls. The age range was wide (8;5 - 17;9, mean age = 11;4 years, SD= 2.16) and participants were divided into three groups according to age for data analysis. Out of the 38 participants, the majority (n = 21) were diagnosed simply with ASD, some (n=10) were diagnosed as having HFA, 5 were diagnosed as having PDD-NOS and finally, 2 were diagnosed as having LFA. In Israel, autism diagnosis is based on the DSM criteria and the terms HFA/ LFA are usually used to describe an individual's daily functioning and how independent (s)he is. Although most participants were diagnosed as having either ASD or HFA, their scores on the nonverbal measure used, Raven's progressive matrices (RPM), did not always correspond to that diagnosis in terms of their nonverbal level. The colored cells are scores of children whose standard score on the Raven's Matrices task was below 80, which is considered the cutoff score from which NVIQ is considered impaired according to task norms.

The CCC was used to assess pragmatic abilities and scores were analyzed in line with the descriptions provided by Bishop (1998). According to these guidelines, a pragmatic composite score was calculated by adding the scores of the five pragmatic subscales (inappropriate intonation, coherence, stereotyped conversation, use of

context and rapport). A pragmatic composite score of 132 is considered the cutoff score for impairment compared to TD.

All participants (except one) attended small special education classes for children with autism that were located inside a regular school. Integration levels varied between schools and between children based on individual abilities to participate in the regular school activities. One child with LFA was homeschooled by his mother, who had undergone ABA training and had a speech therapist and occupational therapist come to the house on a daily basis.

Table 2. ASD participant characteristics

Participant	Gender	Age (y/m)	School Grade	Clinical diagnosis[1]	Raven's Progressive Matrices (Standard score)	CCC (Pragmatic composite score)
TE	M	8;5	3	Autism	65	140
YA	M	8;6	3	PDD-NOS	unable to complete task	110
AM	M	8;9	3	PDD-NOS	85	127
SZ	M	8;11	3	Autism	84	131
ID	M	9;3	3	Autism	68	118
SA	M	9;4	3	Autism	70	126
NA	M	9;4	3	PDD-NOS	unable to complete task	125
MA	M	9;6	3	Autism	98	133
IC	M	9;9	3	Autism	78	128
SH	M	10;2	4	PDD-NOS	unable to complete task	97
SC	M	10;3	4	HFA	98	122

[1] All children had a current diagnosis based on assessment within the last three years; until age seven a reevaluation of diagnosis is required by law every three years, during the transition from elementary school to middle school the ministry of education demands a current evaluation (usually done at the end of 5th grade or beginning of 6th grade), and the same evaluation is required before the transition from middle school to high school (at the end of 9th grade) so that the child's placement would be optimal to suit his needs.

SB	M	10;4	4	PDD-NOS	84	122
DA	M	10;9	4	HFA	75	120
YR	F	10;9	4	Autism	58	105
RO	F	10;6	4	Autism	77	122
BA	M	10;6	4	LFA	unable to complete task	128
MI	F	10;7	5	LFA	unable to complete task	113
YO	M	11.0	6	Autism	75	124
TP	M	11.0	6	Autism	74	147
YU	M	11;2	6	Autism	68	111
AL	M	11;3	6	HFA	105	139
AD	F	11;2	6	HFA	106	132
PE	M	11;4	5	HFA	70	122
TY	M	11;5	5	Autism	78	139
YM	M	11;7	6	Autism	41	101
TZ	M	11;9	6	Autism	63	120
AR	M	11;1	6	HFA	73	122
GA	M	12;7	7	HFA	57	131
YC	M	12;1	6	Autism	104	135
IT	M	12;11	6	Autism	79	138
OO	M	12;11	7	Autism	unable to complete task	121
OM	M	13;2	6	HFA	91	122
MO	M	13;3	6	Autism	86	135
AT	M	13;5	6	Autism	99	138
PT	M	14;7	8	HFA	98	148

SK	M	15;11	9	HFA	111	148
OF	M	17;2	12	LFA	unable to complete task	108
NG	M	17;9	12	Autism	95	147
M 11;4					*M* 81.06	*M* 126.18
SD 2;16					*SD* 16.59	*SD* 12.86

6.1.2.2 Typically developing children

Some of the experimental tasks used in this study were tasks devised for previous research projects conducted at the Brain and Language Lab at the University of Tel Aviv. In the cases in which the control group data corresponded in age to the children with autism in this study, and individual scores could be obtained, we used those groups (number of tasks, n = 5, for detailed description see results chapter). For tasks that were either devised for this study, or for which control groups did not match in age or individual scores could not be obtained, new control data was collected. On tasks for which the youngest control children did not achieve ceiling level scores, the autism group was compared to controls matched in age (n=2).

6.2 Materials

Based on previous research as cited in the theoretical chapter, a model integrating the lexical retrieval model and the dual route to reading model (both described in previous chapter) was created.

The tasks for this research were chosen for their ability to test the different parts of the model and differentiate different locations of impairments based on task performance and error patterns. The current study included 16 different tasks as summarized below. A detailed description of each of the tasks will be presented in

conjunction with results from each of them, in Chapter 7, a summary table of each task is presented in Appendix 1.

6.2.1 Background measures

6.2.1.1 Children's Communication Checklist

The Children's Communication Checklist (CCC) (Bishop, 1998; translated into Hebrew by Friedmann & Novogrodsky, 2007) was used in order to assess pragmatic difficulties along with different aspects of language and communication. Tasks that had an element of free speech (such as the definition task) were tasks that the performance on them could be largely influenced by pragmatic abilities. For this reason a pragmatic score was necessary in order to obtain a clear indication of the participant's pragmatic abilities. A care taker who had daily interaction with the child (parent, homeroom teacher, educational aide) was asked to fill out the checklist. Answers were scored based on the original scoring scheme of Bishop (1998). A pragmatic composite score was calculated by adding the scores of the five pragmatic subscales (inappropriate intonation, coherence, stereotyped conversation, use of context and rapport) as was done in the original study.

6.2.1.2 Raven's Colored Progressive Matrices

Raven's Colored Progressive Matrices (Raven, 1998 - Israeli norms and guidelines - Glantz, 2008) were used to provide a nonverbal background measure. Previous studies have found that children with autism sometimes achieve very high scores on this test compared to regular IQ tests (Hayashi et al., 2007). Each test item is presented on an A4 paper, consisting of a visual geometric design with a missing piece. The participant is given six to eight choices to pick from and fill in the missing piece. The participant is asked to identify the missing element that completes the pattern by pointing to the correct answer. Seven participants (of these, three were

diagnosed as PDD-NOS; three as LFA and one ASD) had trouble understanding the task demands, and some found the task very hard and guessed the answers, in both cases, after five consecutive items with no cooperation the testing of the task was stopped.

6.3 Testing Procedures

In order to familiarize the participants with me, and what I was doing at the school I met all the participants in their classrooms one day prior to testing sessions. I participated in several classes and had one-on-one "free time" with each child playing a game of his choice inside the classroom. The following day when I arrived the participants recognized me and hence were willing to come and participate in a testing session. I met each child individually in a quiet room that was familiar to the child. All sessions were coordinated with the teachers so that the children would not miss classes they liked but rather ones they didn't in order to give them more motivation. All children were told they were helping me with a project and were shown the tape recorder that was recording the session. They were told that we could stop whenever they wanted to go back to class or got tired. On completion of each task the child received a sticker and on completion of each session he received a small snack. The number of sessions for each child varied from 2 to 8 sessions, a smaller number of sessions meant longer session duration (an hour on average), whereas a bigger number of sessions included shorter sessions (on average twenty minutes). All sessions were recorded and transcribed. All sessions were held during the morning hours to prevent results being affected by participant fatigue.

The first session with each child started out with a short, fun game followed by either the Naming task or the Odd-one-out pictures task. Both tasks were administered on a computer and the children were eager to "play". The second test

administered was the Tiltan single word reading test. If the participant was able, the two other Tiltan subtests were administered as well. All other tasks were presented in mixed order across participants taking into account the participants reading abilities as determined by performance on the Tiltan reading test.

6.4. Statistical procedures

For each task, group means and standard deviations were calculated in both the ASD group and the control group. Using Crawford et al., (2010) Singlims program, which includes a t-test for comparison of a single case to a control population, a cutoff score for performance which was significantly different from age controls was established for each task (and age group). This procedure was used to determine impaired versus unimpaired performance on a specific task and later as the basis for the individual profiles.

To test the hypothesis that performance would be better on tasks that test explicit access to semantics versus implicit access to semantics we first categorized the tasks into four categories based on their task demands, ranging from explicit to implicit. Next we calculated a composite score for each category based on the mean of tasks in that specific category. Finally a t-test was run between each of the four category scores of all individuals.

For tasks that had more than one subpart a t-test was administered to test if a significant difference was found between the two parts. On tasks where the participant had to choose between two different possibilities we administered a chi-binomial test to test if their answers were different than chance.

In order to test the assumption that task modality might have an influence on task performance, we conducted a t-test for each individual's scores comparing between all the tasks that had pictures, tasks that had auditory comprehension and

tasks that involved reading. To test if participants did better on abstract items versus concrete items we first made a composite score of all items that were abstract versus concrete for each task in which this differentiation was possible and then compared all composite score (of abstract versus concrete) using a t-test.

In order to test if the background measures used were related to each other and whether any of them affected the other tasks, we used a Pearsons's bivariant two tailed correlation analysis. We then conducted a Pearson's partial correlation and controlled for age and either RPM or CCC, in turn, to see if either of RPM or the CCC were related to the other linguistic tasks. Finally we checked whether the task most directly testing lexical semantics, picture naming, was linked to the other linguistic tasks using a Pearson's bivariant two tailed correlation analysis.

Results

Results will be presented in the following way: The first part of the results presents each of the tasks by principle domain tested and provides group results for each of them. The second section is a presentation of individual profiles according to task scores and error analysis with analysis of impairment location.

7. Group Results

The tasks, and their results, are presented in order of their relative appearance in the Lexical retrieval model and the Dual route to reading model. In many cases a task may test more than one component and in some cases a task may have two parts, each of which tests different components. Each task will be presented individually, including presentation of both parts.

All the tasks in this study were experimental tasks and thus were not age normed. Correlation analysis was made to see whether age was linked to performance on each of the tasks and each of the subtasks. This was the case for the majority of tasks (n = 11). Three other tasks showed a tendency to be related to age (n = 3); the remaining two tasks were not correlated with age. Individual task correlations are presented in Table 2 in the Appendix. Since most tasks were significantly correlated with age or showed a tendency to be, in all tables and graphs the ASD participants are presented in order of chronological age from youngest to oldest.

In all tasks, results are reported as correct answer percentages, in order to allow inter-task comparison, as the number of items varied from task to task. The variability in response patterns in the ASD group was found to be very wide on all tasks used. In each task, each individual score was compared to the control group performance to establish whether it was significantly different or not. In some cases, an ASD participant score was significantly lower than the TD group, and was a relatively low score compared to the other ASD participants as well (e.g. a score of

60% correct). At other times, an ASD participant's score was significantly lower than the TD group, but since the TD group scores were at ceiling levels, even a relatively high score (e.g. a score of 90% correct) was significantly lower. In the next section individual results will be presented and individual scores will be explained with regard to impaired or unimpaired performance (as described in the method section), defined as a score lower than the cutoff score established for each task based on the control group performance on each task.

Each part of the model was tested using several tasks. For each of these groups of tasks we did a Pearson correlation analysis in order to test if the results between the tasks testing the same component were related. Except for the two tasks testing the conceptual component, most inter-task correlations were found to be significant, meaning that the tasks chosen to test the different components from various aspects tested a common component (see Appendix 3 for inter-task correlation analyses).

7.1. Tasks testing the conceptual system

7.1.1 Odd one out task description and control group

This task was built for this research based on the task by Friedmann (2001). The original task had out-dated pictures (an old television set, a hand dial telephone) as well as items that would have been less recognizable by children (and especially children with autism) such as 'kettle' and 'microwave'. The task was built in order to test the participant's ability to associate different members of the same semantic category and differentiate different categories. The task had two parts, pictures and words; each was administered on a different session. The aim of the picture part of the test was to test the conceptual system independently of other components; the aim of the word part was to test the conceptual system, the semantic lexicon, orthographic-visual analysis & orthographic input buffer, and the orthographic input lexicon.

In the picture part, the participant was shown four pictures on a computer screen and was asked to point to the one picture that was different. The task had three difficulty levels: starting with shapes and colours (three rectangles and one triangle). The next level included three pictures of items from a close semantic category and one picture from an unrelated semantic category (e.g., pants, shirt, socks, and zebra). The last level included three pictures of items from a close semantic category and a forth picture that did not belong to that specific category, yet was from a close semantic category (cake, muffin, cookie, and bread).

In the word part of the task, participants were shown four words on a computer screen, and were asked to read them to themselves and then point to the one that was "unrelated". The word part included the same objects that had appeared in the picture part, except for the shape stimuli.

If the participants chose incorrectly, or if they were unable to decide, this was coded as an error. An error analysis was made for each level of difficulty. Participants who had poor reading abilities (as determined by their ability to read the words in the Tiltan reading test) were only administered the picture part.

The control group participants for this task were all typically developing monolingual Hebrew-speaking children recruited from a regular school with no known developmental delays or disabilities (n = 24; 11 girls and 13 boys; *mean age* = 8;7; *SD* = 0;5). This control group was chosen to match the youngest participants in the autism group. All children were studying in the same 3rd grade classroom. Both the school and the parents of the children who were participating in this research were concerned about the number of classes that the children would be missing. For this reason, not all TD children were administered all 16 tasks, but each child was

administered at least three tasks one of which was a reading task in order to rule out reading disabilities.

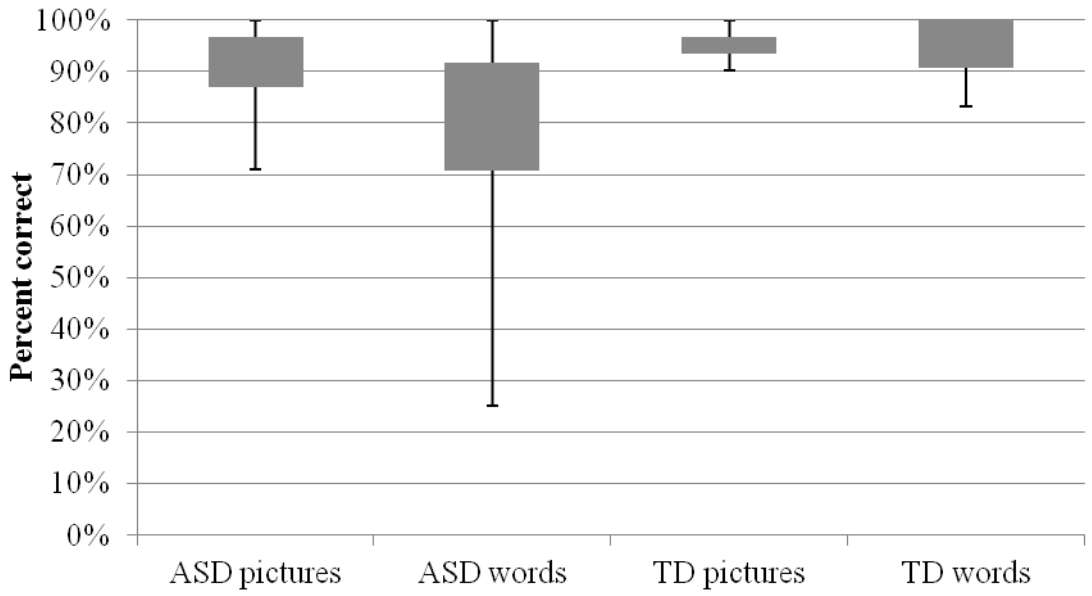
7.1.2 Odd one out group results

The control group participants (n = 16, out of 24) found this task very easy and achieved ceiling scores on both parts of the task (picture part M = 94%; SD = 3; range 90- 100 %; word part M = 95%; SD = 3; range 92-100%), no significant difference between the two parts was observed ($t(15) = 0.05$, $p = .48$).

In the ASD group, not all children achieved ceiling scores, and a significant difference was found between the picture and word parts (picture part M = 90%; SD = 79; range – 71-100%; word part M = 79%; SD = 18; range – 25-100% *;* t (29) = 4.51, $p < .0001$). Two children were unable to complete both parts of the task, possibly due to trouble in understanding the task demands. Both of these participants (YA, SH) had an official diagnosis of PDD-NOS, and were unable to complete the RPM task and had very low pragmatic scores on the CCC (YA: 110, SH: 97). Six participants completed the picture part, but due to poor performance on the Tiltan reading task, the word part of the task was not administered.

The rest of the participants, (n = 30) were administered both parts of the task. Out of these, six participants scored significantly better on the picture part compared to the word part ($p < 0.005$). Figure four, shows the group scores on both parts of the task.

Figure 4. Odd one out (percent correct): ASD and TD

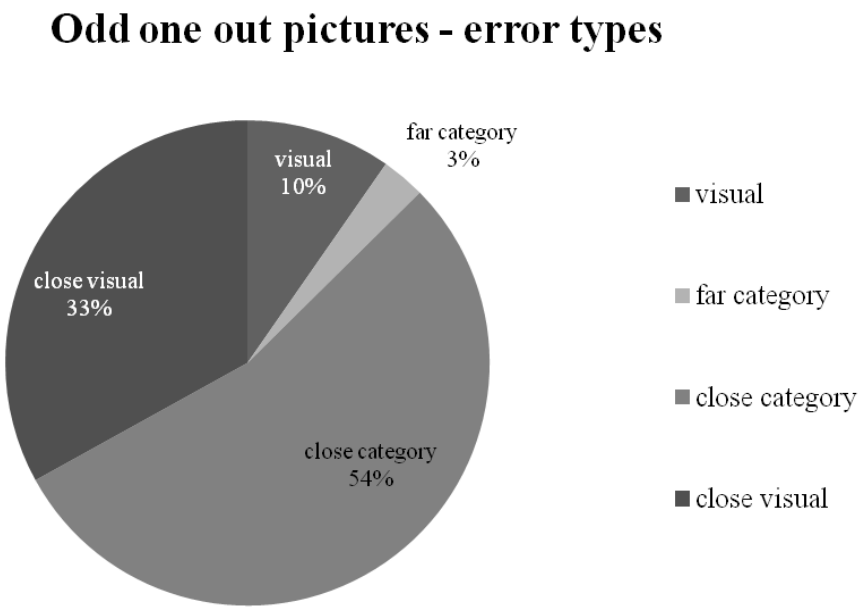


Each part of the task was compared to control group performance and a cut-off score was established based on Crawford et al., (2010) t-test. The cut-off score for impaired performance on the picture part was 90% ($t(15) = -1.940$, $p = .035$) and on the word part 84% ($t(15) = 1.940$, $p = .035$). Out of the 36 ASD participants that completed the picture part of the task, 12 were found to have scores that were significantly lower than the control group. Out of the 30 ASD participants that completed the word part of the task, 19 were found to have scores that were significantly lower than the control group. Out of the 30 ASD participants that completed both parts, ten were found to perform significantly below the control group scores on both parts of the task.

In the picture part, errors were coded according to the level that each item belonged to (based on the properties of the odd one): visually different, belonging to a far category (zebra versus clothes) from the other items, belonging to a close category (bread versus other baked sweets) or being similar visually but belonging to a different category. Out of 103 erroneous responses, the majority of errors were

selection of items that were from a close semantic category (54%) and items that looked visually similar (33%). As seen in figure five.

Figure 5. Odd one out pictures: Error types



On the word part of the test, items were either from close or from far semantic categories. Out of the total of 153 error responses, 127 were on close category items. Only 26 errors were made on far semantic items.

In conclusion, most of the ASD participants were able to complete the picture part of the task; the majority of them also had age equivalent scores. The word part of the task was harder for most ASD participants.

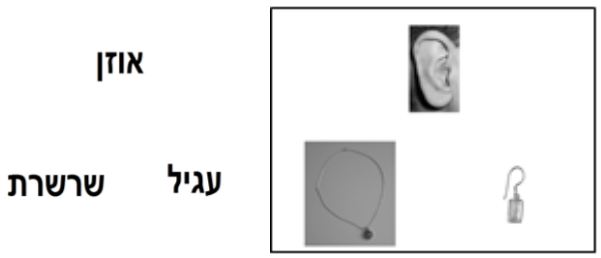
7.1.3 Association task - Pyramids and palm trees: task description and control group

The Association task, taken from the study by Biran & Friedmann, (2007) had two parts, pictures and words. The picture part of the task was aimed at testing the conceptual system and the way that the participants understood relations between objects. The word part, using the same objects only presented as words, was aimed at assessing the conceptual system, the semantic lexicon, orthographic-visual analysis

and orthographic input buffer, and the orthographic input lexicon. Each part was administered during a separate session.

In the first part of the task, the participants were presented with three images: an image shown at the top of the page (ear) and two images displayed at the bottom in equal spaces (necklace, earrings). The participant was asked to look at the top picture and then point to the most appropriate picture that was related to it, picking between the two bottom pictures that appeared in equal spacing. Participants were presented with 35 threesomes of this type. Figure six shows the stimulus as it was presented to the participants in the both parts. In the second part of the assessment, the participants were presented with word threesomes. The target word was presented at the top of the page (ear) and two words displayed at the bottom in equal spacing (necklace, earrings). The participant was asked to read the three words aloud and to point to the most appropriate lower word that matches the upper word. 35 threesomes were presented, the first 25 were the same words as in the pictures part and the last 10 threesomes included abstract words (laughter - joy, tears).

Figure 6. Association task: example items



For each participant, the number of correct answers was counted and a chi test was used to determine if the difference between performances on the two task parts was significant. Participants who had poor reading abilities (as determined by their ability/inability to read the words in the Tiltan reading test) were only administered the picture part. Individual error patterns were investigated and will be reported in depth in the individual profiles in the next chapter.

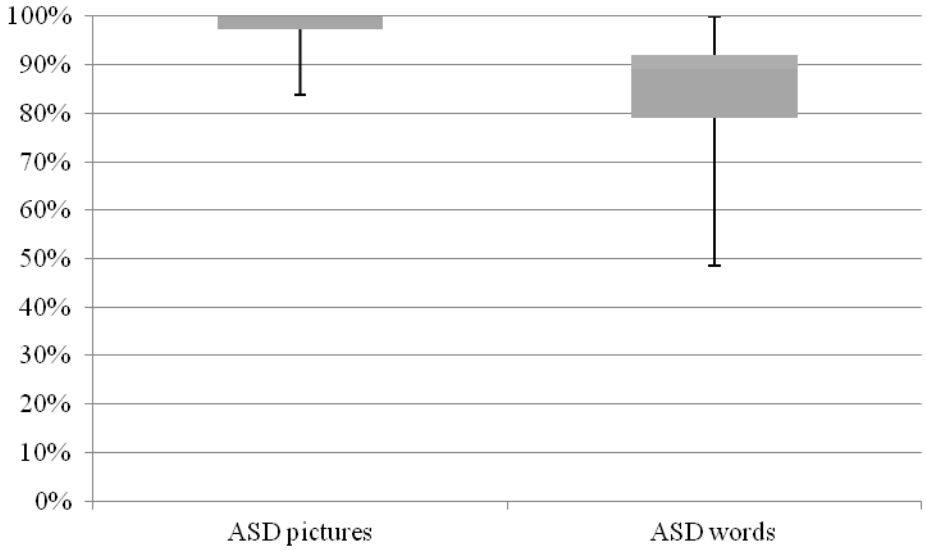
The control group for this task was made up of children from the study by Fatal, Friedmann & Fattal-Valevski (2011). All children (*n* = 17, 8 girls, 9 boys) were typically developing monolingual Hebrew speaking children attending 2nd grade in a regular school (*mean age* = 8;2, *SD* = 0;3). None had a developmental delay or disorder.

7.1.4 Association task - Pyramids and palm trees: group results

The control group participants, who were all younger than the ASD group participants, performed at ceiling levels on both parts of the task (Picture part *group mean* = 100%, *SD* = 0; Word part *group mean* = 99%, *SD* = 9) and no significant difference was found between performance on the different parts of the task ($t(16) = 1.46$, $p = .08$).

In the ASD group, not all participants were able to complete the task; one participant did not understand the task demands and another refused to cooperate. Six more participants were administered only the picture part of the task due to poor reading abilities (as determined by their abilities or inability to read the words in the Tiltan reading test). As a group, scores were significantly higher on the picture part of the task (picture part *n* = 36, *group mean* = 97%, *SD* = 4, range = 84-100%; word part *n* = 30, *group mean* = 85%, *SD* = 13, range = 49-100%; $t\ (35) = 5.88$, $p < .0001$). A chi square test was used to test the difference between the two task parts; 22 participants scored significantly better on the picture part compared to the word part ($n = 22$; $p < 0.05$; $n = 9$, $p < 0.0001$) as shown in Figure seven.

Figure 7. Association task (percent correct): ASD participants



In the word part of the task, the last ten items were abstract words. Children in the ASD group performed significantly better on the concrete items compared to the abstract items ($t(29) = 5.76$, $p < .0001$; no such difference was found in the control group ($t(16) = 1.46$, $p = .08$).

Each part of the task was compared to control group performance and a cut-off score was established based on Crawford & Garthwaite's (2010) t-test. On the picture part of the task, the control group achieved ceiling scores with a SD of 0 (two mistakes total) and so the cut-off score for impaired performance on the picture part was 95%; 3 ASD participants had scores that were lower than this score. On the word part of the task the cut-off for impaired performance was 98% and 24 ASD participants achieved a score that was lower.

In conclusion, most ASD participants were able to complete the picture part of the task with TD equivalent scores. As a group, the scores on the word part of the task were significantly lower than on the picture part, and, furthermore performance in the word part on abstract items was worse than on concrete ones.

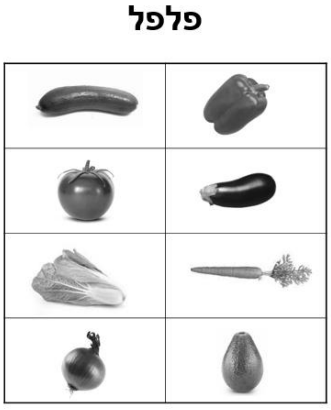
7.2 Tasks testing the conceptual system, semantic lexicon, Orthographic-visual analysis and orthographic input buffer, orthographic input lexicon

Two subparts of tasks that have been described in previous sections test these parts of the model, the words subpart of the Odd-one-out task (7.1.1), and the words subpart of the Association task (7.1.3). To these a third task was added.

7.2.1 Word Picture matching ("Pilpel"): task description

This task was built for the current research with the aim of testing the participant's ability to choose a semantic representation out of a semantic category while matching a word with its correct pictorial referent. The participants were shown a computer screen that had a word written at the top, below the word were eight pictures including the target picture and seven other pictures from the same or a close semantic category. Participants were asked to read the word out loud and point to the matching picture. Participants who had low scores on the Tiltan reading test were read the word by the experimenter and asked to point to the correct picture. Answers were counted for correct responses.

Figure 8. Example item: word picture matching



פלפל

Pilpel

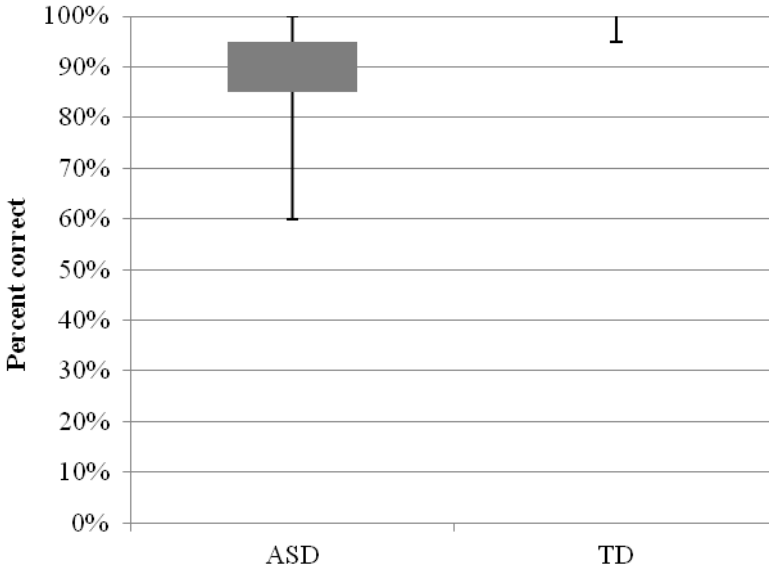
Bell pepper

The control group was the same as that described in Section 7.1.1.

7.2.2 Word Picture matching: group results

This task was one of the tasks which all 38 ASD participants were able to complete and for which the task demands were understood by all. The TD group of children performed at ceiling levels (TD group: n = 16, M = 99%, SD = 2, range = 95-100%) and although the ASD group scores were relatively high (ASD group: n = 38, M = 90%, SD = 9, range = 60-100%), the range goes much lower and a significant difference was found between the two groups (t (37) = -6.35, p < .0001). The cut-off score for impaired performance as assessed by the Crawford & Garthwaite, (2002) t-test was 95% (t (15) = 1.940, p = .03). Out of the 38 ASD participants, 19 performed significantly below that level.

Figure 9. Word picture matching (percent correct): ASD and TD



In summary, it seems that most of the ASD participants were able to match a written word with its pictorial referent, although not always at an age equivalent level.

7.3 Tasks testing the conceptual system, semantic lexicon, phonological output lexicon and phonemic output buffer

7.3.1 Picture naming ("Shemesh"): task description

This task was taken from the study by Biran & Friedmann, (2004). The aim of this task was to evaluate the participant's naming abilities. If the participant produced the correct name we could see that the participant is capable of producing the correct word, and hence, going correctly through all the stages of naming an image after identifying the image: semantic lexicon, phonological lexicon and the output phonological lexicon. It was also possible to check whether the participant understood and recognized the image displayed.

Participants were shown 100 pictures of nouns. Each picture appeared on a computer screen which displayed a single image. The participant was asked to name the displayed image. There was no time limit and the participant was told that he should say the first word that he was thinking of. The number of correct answers was counted for each participant as well as the number of correct answers after hesitation (for ex. If a participant hesitated, said 'ahhh' or made a gesture and then produced the correct target word). Each incorrect answer was classified according to the following categories: unrelated (*Ozen aman*, a special holiday cookie for Purim, produced for target ‘sleeveless shirt’), semantic paraphrasing inside a semantic category (target: axe; production: hammer), associative semantic (target: necklace; production: lady), naming of the big semantic category (target: boots; production: shoes), definition (target: lighter, production: makes fire), partial definition (target: pan, production: cook with), gesture only, phonological error, 'don’t know', visual error (target: belt, production: leash). Errors were also analyzed according to their semantic category affiliation (food, clothing, animals, body parts, vegetables, writing tools, kitchen ware, musical instruments, electronic appliances, fruits, miscellaneous, transportation

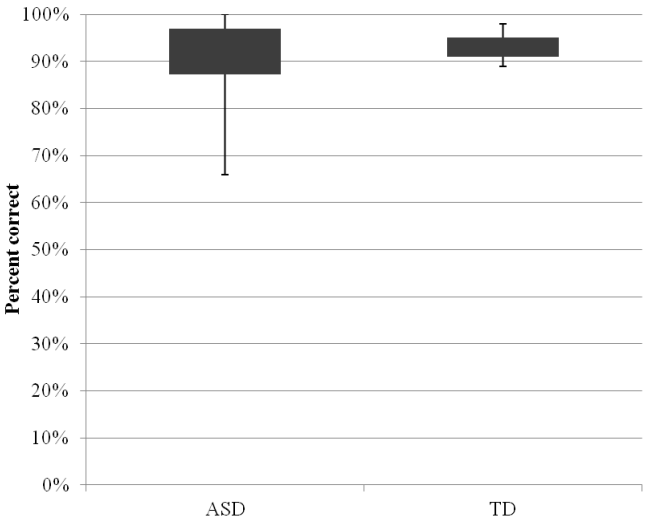
or jewelry) and frequency affect was tested according to the frequency of the word (Biran & Friedmann, 2004; 2005).

The control group for this task was the control group described in Section 7.1.3.

7.3.2 Picture naming ("Shemesh"): group results

All 38 ASD participants were able to complete this task. Although the mean score of the ASD and the TD groups were not significantly different, the range of responses was much wider in the ASD group (TD group: n = 17, M = 92%, SD = 2, range = 89 – 98%; ASD group: M = 91%, SD = 8, range = 66 – 100%, t (37) = 0.25, p = .41). The cutoff score for this task based on the TD group's performance was 88% correct answers.

Figure 10. Picture naming (percent correct): ASD and TD



In both groups the most frequent errors were errors of semantic paraphrasing, providing a definition instead of the target noun, and stating ‘I don’t know’. In the ASD group associative semantic and partial definition errors were observed that were not seen in the TD group.

7.4. Tasks testing the Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon

7.4.1 Word association task ("Ma Kashur"): task description

This task was taken from the study by Biran & Friedmann (2007) with the aim of testing the participant's ability to semantically associate between two written words and differentiate between homophones. The task included 40 triads; each triad contained a target word (placed at the top of the screen) and two words (placed at the bottom of the screen with equal distance from each other and from the target word above). One word was associated semantically with the target word and the other word was a homophone of the associated word. The participants were asked to read the target word and then point to the word which was semantically associated to the target word (Ma Kashur? 'What's related?' --pencil *eparon*: write *kotev*/north pole *kotev* – different spelling in Hebrew). Participants who were unable to complete the Tiltan word reading task were not administered this task. Correct responses were counted for each participant.

The control groups for this task were age equivalent TD children who had participated in previous studies at the Brain and Language lab at Tel Aviv University. Control group characteristics are shown in Table 3 in the following section.

7.4.2 Word association task (Ma Kashur): group results

Table 3. Word Association task (Ma Kashur): Correct answers, mean (*SD*), range and comparative statistics

	TD Groups			ASD			
	n Participants	*M* Score (SD)	Range	*n* Participants	*M* Score (SD)	Range	Statistics : ASD vs. TD
3rd grade	15	0.83 (0.15)	0.65 -1	11	0.77 (0.14)	0.55- 1	t (10) = -0.64, p =.268
5th grade	18	0.94 (0.05)	0.83 -1	10	0.89 (0.11)	0.63- 1	t (9) = -1.30, p =.112
7th grade	24	0.97 (0.02)	0.90 – 1	8	0.95 (0.06)	0.80 - 1	t (6) = -0.51, p = .315
Adults	9	0.99 (0.01)	0.98 – 1	2	0.99 (0.017)	0.98- 1	

No significant difference between group scores (ASD vs.TD) was found. In the ASD 3rd grade group, six participants were unable to complete the task (their scores were not analyzed) and one participant had a significantly lower score compared to controls (cutoff score: 55%; t (14) = 1.807, p = .046). In the 5th grade ASD group, all participants completed the task, but four had significantly lower scores than the control group (cutoff score: 85%; t (17) = 1.752, p = .005). In the 7th grade ASD group one participant was unable to complete the task and one had significantly lower scores than the control group. Finally in the oldest ASD participant group who were compared to an adult group of TD participants, one ASD participant was unable to complete the task while the other two performed like controls.

In summary, most ASD participants were able to semantically associate two written words and differentiate between homophones at least partially.

7.5 Tasks testing the orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer

7.5.1 Reading test ("Tiltan"): task description

This task was taken from the study by Friedmann & Gvion, (2003). Tiltan is a reading screening test devised to detect different kinds of dyslexia. For the current research only three subtests out of the battery were chosen in line with the different components of the model that needed to be tested: single words, nonwords, and pairs of words. The participants were shown 136 single words, 30 non-words and 30 pairs of words. The single words and word pairs test the orthographic-visual analysis and orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer. The non-words subtest was administered in order to test the orthographic-visual analysis and orthographic input buffer, grapheme-phoneme conversion and the phonemic output buffer. The participant was asked to read these words aloud as accurately as possible with no time constraints. For each participant the number of correct answers was counted and errors were analyzed following the error analysis presented in Friedmann & Gvion, 2003. Participants who had difficulty with the task were administered each subpart on a different session. Participants who were unable to finish reading the first page of the single word reading subtest (which consisted of 27 words) or read all 27 of these words incorrectly were not administered the rest of the test.

Control group participants included the same children in third grade described in Section 7.1.1, as well as older typically developing children with no known neurological or developmental delays or disabilities that were collected for different studies at the Brain and Language lab at Tel Aviv University. The ASD scores were compared to their age equivalent control group.

7.5.2 Reading test ("Tiltan"): group results

This task, the first task administered to all the participants, assessed reading abilities and determined whether further tasks involving reading could be completed. Out of the 38 ASD participants, 7 were unable to complete the test. Table four presents the mean scores and SD for the control groups and ASD group for each of the three subtasks of this test.

Table 4. Tiltan Reading Test: Scores (M percent correct (SD)), ASD and TD

	Single words		Nonwords		Word pairs	
	TD	ASD	TD	ASD	TD	ASD
3rd grade TD: *n* = 11 ASD: *n* = 7	94(6)	77 (13)	93 (7)	90 (9)	94 (5)	86 (8)
4th grade TD: *n* = 20 ASD: *n* = 6	91 (5)	89 (12)	85 (13)	90 (7)	88 (5)	92 (12)
5th grade TD: *n* = 14 ASD: *n* = 10	96 (3)	92 (6)	93 (5)	93 (8)	95 (4)	96 (4)
7th grade TD: *n* = 26 ASD: *n* = 9	96 (1)	93 (3)	94 (5)	94 (6)	96 (4)	94 (4)

In the youngest control group (3rd grade), no significant difference was found between the three parts of the test (single/non words: t (10) = 0.65, p = .26; single / pairs: t (10) = 0.18, p = .43; nonwords / pairs: t (10) = 0.72, p = .24). In the fourth grade control group a significant difference was found between the scores on the single word reading part and the nonword reading part and between single word

reading and word pair reading, but not between the nonwords and word pairs (single/non words: t (19) = 2.00, p =.03; single / pairs: t (19) = 2.86, p =.005; nonwords / pairs: t (19) = 1.05, p = .15). In the fifth grade and seventh grade control groups a significant difference was found between the scores of the single word reading part and the nonword reading part but not between the single word reading and the word pair reading part or between nonwords and word pairs (fifth grade control group: single/non words: t (13) = 2.14, p = .026; single / pairs: t (13) = 1.71, p =.055; nonwords / pairs: t (13) = -0.95, p = .18; seventh grade control group: single/non words: t (25) = 1.75, p = .046; single / pairs: t (25) = 0.48, p = .014; nonwords / pairs: t (25) = -1.20, p = .12). In the ASD group a significant difference was found between the scores of the single word reading part and the nonword reading part and between the single word reading and the word pair reading, but not between nonwords and word pairs part (single/non words: t (31) = 1.87, p = .035; single / pairs: t (31) = 4.11, p = .0001; nonwords / pairs: t (31) = 0.25, p = .40).

On the single word reading part, 13 ASD participants had scores significantly lower than their age equivalent TD group, on the reading of pairs of words, 7 ASD participants were found to have scores significantly lower than their age equivalent TD group and on the nonword reading part only 3 ASD participants were found to have scores significantly lower than their age equivalent TD group. Only two participants were found to have significantly lower scores than their age equivalent TD group on all three parts of the task. Further analysis of the individual patterns seen in the ASD group will be discussed in the next chapter, on individual profiles.

A majority of children with ASD, when making errors, made errors that were of reading the target word via the sub lexical route (as if this was a new word they had never seen before). These errors are commonly seen in young TD children. Errors of

letter migration, omitting, morphological errors and phonological errors were rarely seen and were typical of a few specific individuals.

In summary, a major group of ASD participants seems to have intact reading abilities, and most of the group was able to perform on the nonword reading test at an age equivalent level.

7.6 Tasks testing the Phonological input buffer, phonological input lexicon, semantic lexicon and conceptual system

7.6.1 Semantic phonological input word memory ("Probe"): task description

Based on the task for adults with aphasia by Gvion & Friedmann (2008), FriGbi Battery, this task was modified from its original version by changing items to include words that would be recognizable by children. This task was originally used to test recognition memory; in this study the task was used to test the phonological input buffer and phonological input lexicon, as well as to see if there might be a semantic or phonological coding effect.

The participant heard lists of eight two-syllable words that varied in frequency, in abstractness and in lexical and semantic affiliation. The participant heard first an uninterrupted list of eight words at a rate of a word per second and then asked whether each word in a second list of eight words had appeared on the first list or not. In the second list, half of the items were items that had appeared on the first list and the other half included semantic and phonological distracters (car/vehicle, *chalon* (window)/*balon* (balloon)). The number of semantic and phonological distracters for each list was identical and their positions changed in each list. Each participant heard a total of 20 lists. For each participant the number of correct responses was counted and analyzed to determine if it differed from chance by using binominal test. An error analysis was conducted to see if there was a difference

between semantic and phonological distracters (individual patterns will be presented in the individual profile chapter).

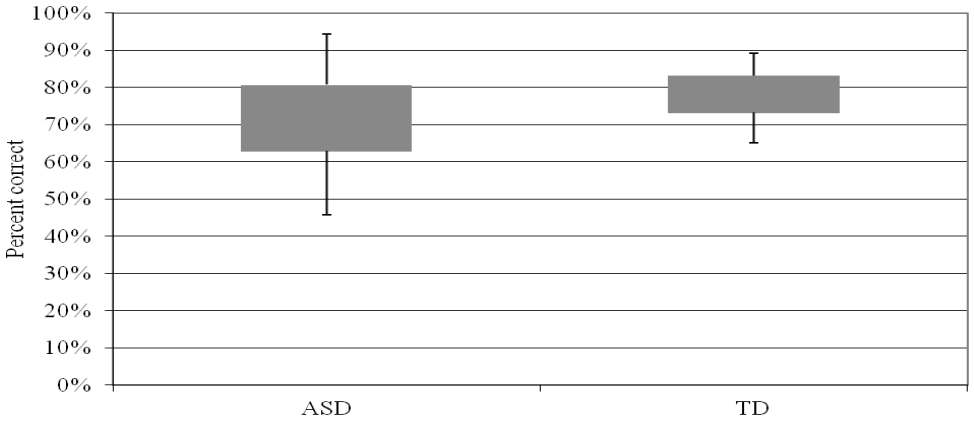
The control group for this task was the same children described in Section 1.1.1.

7.6.2 Semantic phonological input word memory ("Probe"): Group results

Both the control group and the ASD group found this task to be very hard. Most ASD participants had trouble cooperating on this task and in some cases it was administered during two different sessions; in this case the first ten stimuli lists were presented in the first session and the second ten stimuli were presented in the second session. No difference in performance was found between the two sessions and so scores were treated as one session in all cases. Some participants had a hard time understanding the task; in some cases participants refused to cooperate or repeated the same answer throughout (always said yes / no); in these cases three lists of stimuli were administered and then the test was stopped and performance was not used in group results.

In the control group 11 children completed the task (three other children answered "yes" to all stimuli and therefore were not given the entire task). In the ASD group, out of 38 children, only 23 were able to complete the task (some didn't understand the task demands while others didn't cooperate). The difference between the group means was not significant, but the SD and range in the ASD group was much larger (TD group: *group mean* = 77%, *SD* = 7, range 61-89%; ASD group: *group mean* = 71%, *SD* = 14, range 46-94%; t (22) = 0.38, p = .37. The distribution of correct answers of the ASD and the TD group is shown in Figure 11.

Figure 11. Semantic phonological input word memory (percent correct): ASD and TD



In both groups, no significant difference was found for any of the participants between the semantic and the phonological distractors.

In conclusion, this task was very hard for both the ASD and the TD participants and although the ASD participants were older, they achieved similar group scores. Variability of responses was very big and so group conclusions are hard to make.

7.7 Tasks testing the Phonological output buffer, phonological lexicon, conceptual system, semantic lexicon, phonological output lexicon, phonemic output buffer and syntax

7.7.1 Sentence repetition task "Petel": task description

The aim of the “Petel” Sentence repetition task (Friedmann, 2000) was to test the phonological output buffer, phonological lexicon, conceptual system, semantic lexicon, phonological output lexicon, phonemic output buffer and syntax. In the original task, the experimenter read the sentences out loud and the participant was asked to repeat them. In order to enhance motivation for completion of the task, it was turned into a game. All sentences were prerecorded and a game course was presented on a computer screen. With every sentence the participant repeated (regardless if it

was correct) a turtle advanced in the course until reaching the end. At certain points in the "game" the participant received a small prize and in others an encouraging slide popped up. The participant was asked to listen to a sentence, count out loud to three and then repeat the sentence exactly as he heard it. The participant was asked to count to three so as to prevent phonological memorization in the phonological loop (Baddeley, 1997) and hence automatic repetition. The task consisted of 70 sentences. Before starting, a sample sentence was shown to make sure the participant understood the task. This sentence was not part of the data analysis. If the participant was unable to count to three and then repeat the sentence for five sequential sentences he was asked to listen to the sentence and repeat it immediately without counting. Sentence types included:

(1) Simple sentences

אתמול אמא ישנה במיטה

Etmol ima yashna b'mita

'Yesterday mom slept in the bed'

(2) Sentences with verb movement

אתמול ביקר הילד חבר

Etmol biker ha'yeled haver

'Yesterday the boy visited (a) friend'

(3) Embedded sentences

אמא אמרה שהחלב נגמר

Ema amra she'hahalav nigmar

'Mom said the milk finished'

(4) Sentences with Accusative movement

אתמול הילד נפל בגינה

Etmol ha'yeled nafal ba'gina

'Yesterday the boy fell in the yard'

(5) Sentences with WH movement

את איזו מורה הילדה אוהבת?

Et aizo morah ha'yalda ohevet?

'Which teacher does the girl like?'

The correct productions were counted for each of the sentence types separately as well as for the whole task. The errors were classified as structural errors (when a participant changed the grammatical structure of the target sentence) or lexical errors (when the participant maintained the structure of the sentence but changed the nouns or verbs in it).

Three groups of typically developing children were used for this task. Groups were part of language studies ongoing at the Brain and Language lab at Tel Aviv University and data was collected and analyzed by Ronit Szterman, Maya Yachini and Nufar Sukenik. Participants were 50 TD children divided into three groups according to age (group 1: 7-9 years; group 2: 10-11 years; group 3: 12-18 years). All children were studying in a regular school and had no known physical or neurological disabilities. Each one of the ASD participants was compared to the age equivalent group of TD children.

7.7.2 Sentence repetition task – group results

Control group participants (including the younger ones) found this task to be very easy. Table five shows the percentage of correct overall score for each of the control groups.

Table 5. Repetition task: TD group results

	N	Age range	Mean age (SD)	Percent correct: *M* (SD)
Group 1	11	7 - 9 years	8;7 (0.9)	97 (2)
Group 2	19	10 – 11 years	11;0 (0.53)	98 (3)
Group 3	20	12 – 18 years	14;1 (2.12)	96 (4)

In all the control groups, no significant difference between sentence types was observed and in all groups, errors, if present were usually structural errors (changing of the sentence structure but keeping the NPs and verbs of the target sentence).

In the ASD group, the variation of overall scores was very big with some participants scoring at an age appropriate level while others were unable to complete the task (n = 7). The seven participants who did not complete the task seemed not to understand the task demands. Out of the 31 participants who completed the task, only eight achieved age equivalent scores, the remaining 23 scored significantly lower than their age equivalent TD peers. Figure 12 shows the percentage of correct scores for the ASD group.

Figure 12 . Sentence repetition task ASD performance (percent correct)

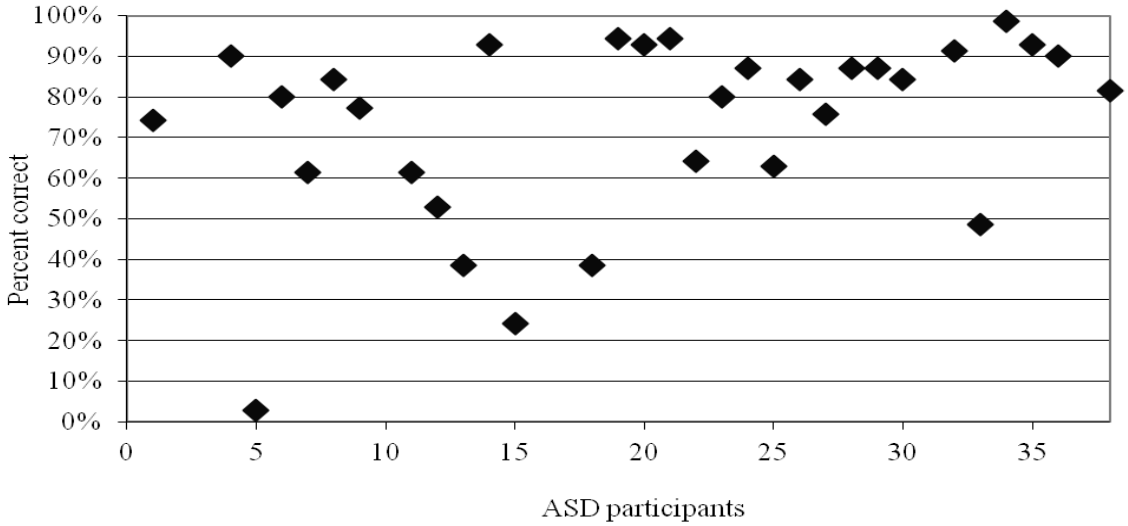


Figure 13.Sentence repetition ASD group results (percent correct) by sentence type

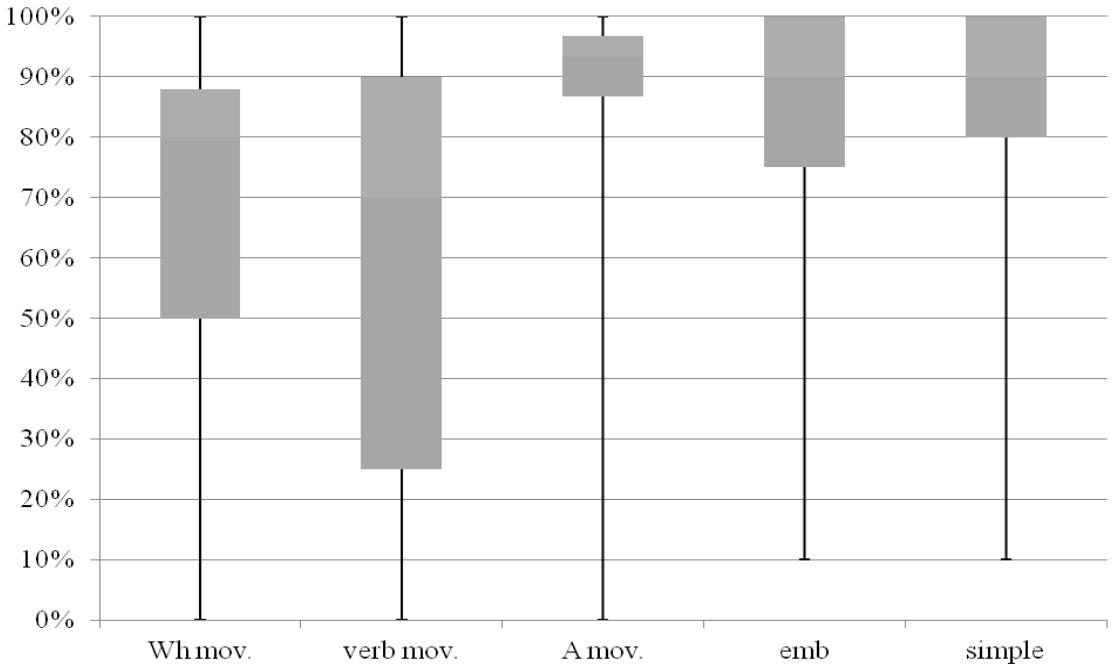


Figure 13 shows group results of correct percentages according to sentence types. ASD participants (regardless of their age group) repeated sentences with WH-movement less accurately than all other sentences types. As a group, no differences were found between the rate of lexical errors (changing one of the NP's or the verbs in

the sentence) and structural errors (on average: *M* = 13.3, *SD* = 13.76; *M* = 14.29, *SD* = 8.16 respectively).

Summarizing, some ASD participants had very low scores on the sentence repetition task. The ASD group performed significantly lower than age-matched TD children.

7.7.3 Sentence comprehension (Similar semantic/ phonological NP "Meguvana"): task description

This task was part of the "Bambi" battery created by Friedmann and Novogrodsky (2002). The aim of this task was to test the participant's comprehension of subject and object relative sentences that have similar NP's. Half of the sentences were sentences with NP's that were phonologically similar (*shaan* – 'watchmaker' / *shafan* – 'hare') and half were sentences with NP's that were semantically similar (princess/ queen). The aim was to test whether there would be a difference between the two sentence types that might indicate that children with ASD favor phonological or semantic coding of information. If participants code the information they hear phonologically – more mistakes would be seen on the phonologically similar NP sentences. But if they code the information semantically, we would expect more mistakes on the sentences with the semantically similar NPs. The nature of this task means that it taps into the phonological output buffer, phonological lexicon, conceptual system, semantic lexicon, phonological output lexicon, phonemic output buffer and syntax. The participant heard 48 sentences; for each sentence he was asked to listen carefully and then answer a question regarding one of the participants. Example 6 is an example of a sentence with phonologically similar NP's, example 7 is an example of a sentence with semantically similar NP's.

(6) Phonologicaly similar NP

הגמל שדחף את הגמד חייך...את מי דחפו?

Ha'Gamal she'dachaf et ha'gamad xiech…et mi dachafu?

'The camel that pushed the dwarf smiled…who was pushed?'

(7) Semantically similar NP

הקרפדה שליקקה את הצפרדע צחקה...את מי ליקקו?

Ha'karpada she'likeka et ha'tzfardeah tzachka…et mi likeku?

The toad that licked the frog laughed…who was licked?

If the participant had trouble understanding the sentence, it was read to him for a second time. Correct answers were counted for each participant and error analysis was made according to sentence type.

The control group for this task was comprised of the same children described in Section 7.1.1 (n = 11).

7.7.4 Sentence comprehension- Similar semantic/ phonological NP: group results

The aim of the current task was to test a difference in sentences with similar semantic/ phonological NP's. The scores of the participants in the control group were significantly higher than those of the ASD participants (TD group: n = 11, M = 87%, SD =10, range 60-96%; ASD group: n = 32, M = 64%, SD = 16, range 31-94%; t (29) = 4.02, p = .001). Out of the 38 ASD participants, 6 were unable to complete the task due to not understanding the task demands and 18 were found to have scores that were significantly lower than the control group. Figure 14 shows the percentage of correct answers of the ASD and TD group. In the TD group, no significant difference between semantic and phonological distracters was found (t(10) = 0.41, p = .35). In the ASD group, on the other hand, a significant difference between semantic and

phonological distracters was found (t (29) = 2.14, p = .02), but this difference was mainly due to three individuals who scored significantly better for semantic than for phonological distracters. None of these three participants had a significant difference on their performance for subject versus object relative sentences. However, on the group level, both the TD participants and the ASD participants scored significantly better on subject relatives compared to object relatives (t (10) = 6.17, p = .0001; t (29) = 5.92, p < .0001).

Figure 14. Sentence comprehenshion, similar semantic/ phonologic NP's (percent correct): ASD and TD

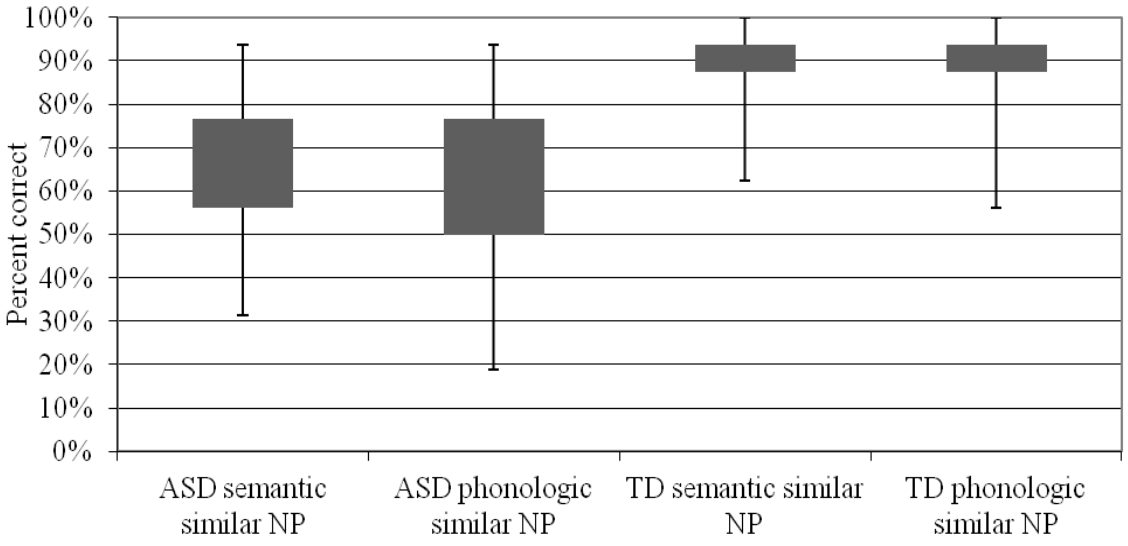
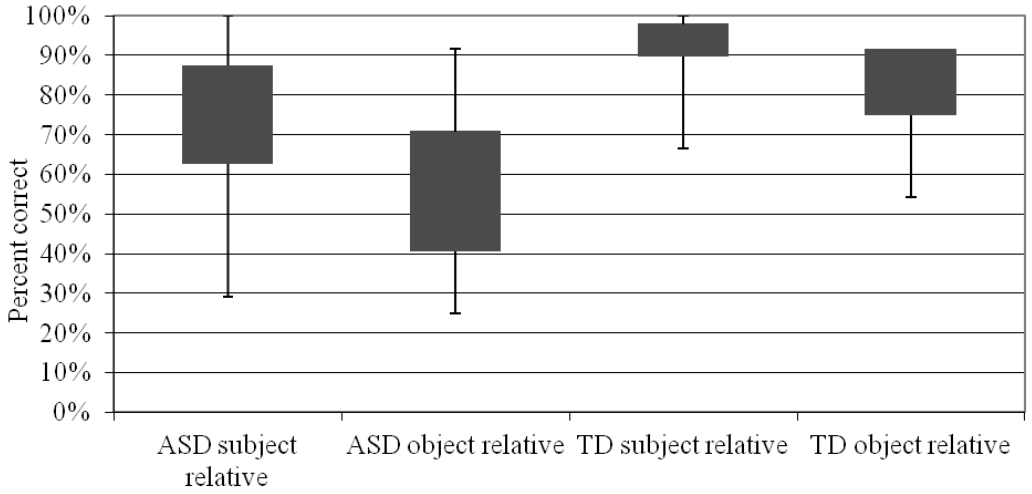


Figure 15. Sentence comprehenshion, similar NP's subject relative / object relative sentences (percent correct): ASD and TD



In summary, both the ASD group and the control group results varied widely and both groups achieved better scores on sentences with a subject relative clause. For the TD participants the different types of NP's in the task had no effect on their scores, while the ASD participants had lower scores on items with similar phonological NPs.

7.8. Tasks testing the Phonological input buffer, phonological input lexicon, conceptual system, semantic lexicon and syntax

7.8.1 Semantic-syntactic reactivation sentence-picture matching ("Mekayim"): task description

This task was based on the task created by Friedmann and Gvion (2003). Since the original task had outdated pictures that depicted a very limited array of situations, it was revised to include more verbs that would be familiar to children and new pictures were drawn. The original task had a large number of items; in order to shorten the task only sentences with a two-word distance and sentences with a nine-word distance were used.

This task tested the phonological input buffer, phonological input lexicon, conceptual system, semantic lexicon and syntax. It did not require verbal output. The aim of the current task was to test semantic-syntactic reactivation by assessing the comprehension of relative clause sentences. In particular, we sought to determine if comprehension of relative clauses is impaired when other semantic abilities seem to be impaired and whether increasing the distance between the antecedent and the gap has an effect on comprehension. For example, in the object relative sentence in example eight, understanding the sentences requires filling in the missing direct object of 'drying'--'this is the mother the daughter is drying *her*':

(8) Object relative sentence

זו האמא שהילדה מנגבת

This is **the mother** *the daughter* is drying ___

In sentences in which the distance between the antecedent ('the mother') and the gap that needs to be "filled" is long (see examples nine and ten), and in particular when a syntactic element of the same types as the antecedent intervenes between them, 'the daughter' in example eight, the harder the sentence is to understand (see Friedmann et al. 2009).

The participant was presented with two pictures side by side on a computer screen. Each picture included two figures, one figure performing an action on the other. One picture matched the target sentence and the second depicted the same characters and the same action, but with reversed thematic roles (the agent in the sentence heard is the patient in the picture, and vice-versa). Before hearing the target sentence, participants were asked to identify the characters in the pictures. Then they were asked to listen carefully to a sentence and point to the picture that matched the sentence heard. The participant heard 44 sentences with semantically reversible

subject and object relative clauses that were split into two parts, each part administered at a different session. Half of the sentences included two words between the antecedent and the gap and half included nine words between the antecedent and the gap. Correct answers were counted for each participant. Not all participants were able to complete the task; if a participant refused to cooperate, or if for five consecutive sentences pointed to the same side on the screen, testing of the task was stopped.

(9) Subject relative, two word distance

זה ***הילד*** הקטן והחייכן ***שרוחץ*** את האבא

Ze ha'yeled ha'katan ve'ha'chaychan she'rochetz et ha'abba.

'This is the small, smiling little boy that is bathing the father'

(10) Object relative clause, nine word distance

זו ***הילדה*** הרצינית עם השיער הקצר הבהיר עם השרוולים התפוחים המצחיקים ***שמצלמת*** את האחות.

Zu ha'yalda ha'retzinit im ha'seaar ha'katzar ha'bahir im ha'sharvulim ha'tfuchim ha'matzchikim she'metzalemet et ha'achot.

'This is the serious little girl with the short light hair and the funny puffy sleeves that is photographing the nurse'

7.8.2 Semantic-syntactic reactivation sentence-picture matching ("Mekayim"): group results

The fact that this task was administered on a computer screen seemed to help motivate participants from both groups to cooperate with the task. The TD group included the same participants described in Section 7.1.1, who were younger than most ASD participants. As a group the TD participants achieved significantly higher scores than the ASD group and variability in responses in the ASD was very wide (TD group: n = 16, M = 98%, SD = 3, range = 86-100%; ASD group: n = 31, M = 82%, SD = 13, range = 57-100%, t (30) = 3.53, p = .0015).

Figure 16. Semantic-syntactic reactivation sentence picture matching gap diffrence (percent correct): ASD and TD

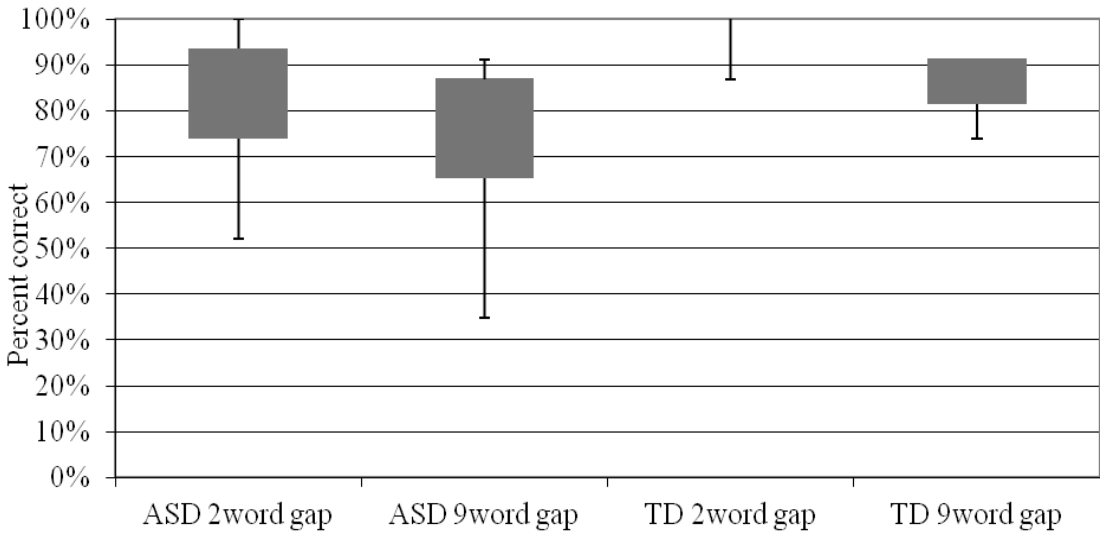
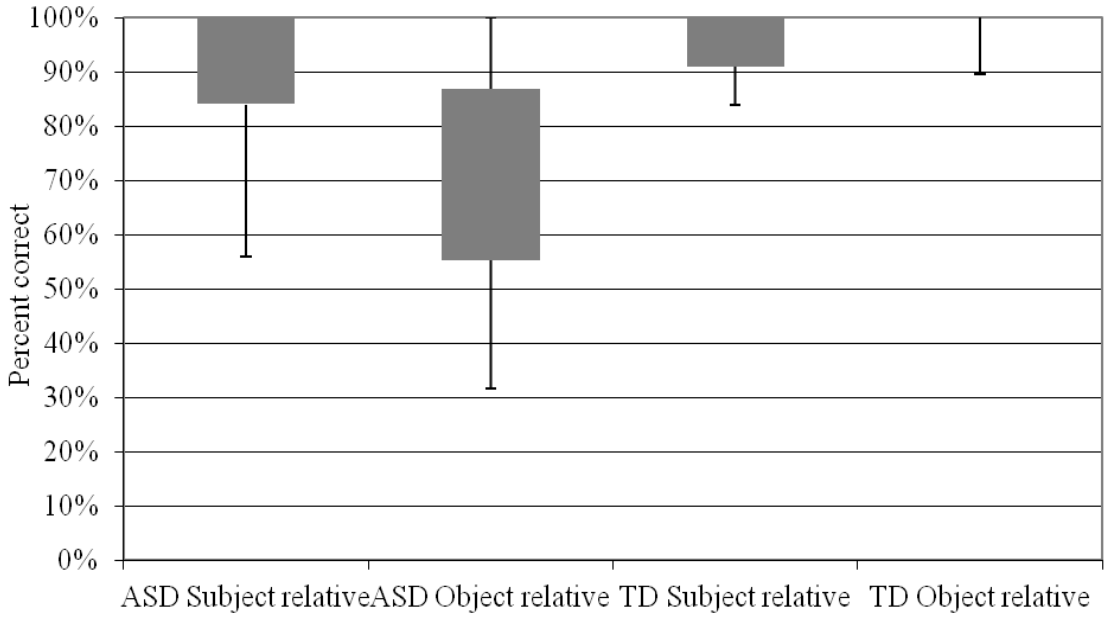


Figure 17. Semantic-syntactic reactivation sentence picture matching subject/object relatives (percent correct): ASD and TD



Both groups were found to have significant differences in their performance on the different word distances. Scores on sentences with a two-word distance between the antecedent and the gap were higher than sentences with a nine-word distance between the antecedent and the gap (TD: t (15) = 9.93, $p < .0001$; ASD: t (30) = 4.32, $p = .0001$), as well as a significant difference was found in both groups in favor of subject relative sentences versus object relative sentences (TD: t (15) = 3.13, $p = .0035$; ASD: t (30) = 5.46, $p < .0001$).

Out of the 38 ASD participants, seven were unable to complete the task due to lack of cooperation or lack of understanding the task demands (it was not always possible to tell the difference between the two).

Five ASD participants were found to have significantly higher scores on sentences with two words between the antecedent and the gap compared to sentences with nine words between the antecedent and the gap. Three of these also understood

subject relatives significantly better than object relatives, as was the case for a total of 19 of the 31 ASD participants who completed this task.

In summary, although most participants were eager to cooperate, this task seems to be sensitive to comprehension difficulties associated with object relatives and most participants with ASD were affected by the number of words between the antecedent and the gap.

7.9. Tasks testing the Phonological input buffer, phonological input lexicon, conceptual system, semantic component, syntax, Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon

7.9.1 Pronoun agreement judgment: task description

The aim of this task was to test grammatical understanding in sentences with relative clauses and see whether participants are able to identify ungrammatical sentences and explain why they are so. In order to do so, the participant must understand the sentence and be able to judge the grammatical components of the sentence. Each participant was shown two sentences side by side. One sentence was grammatically correct and the second was not. The participant was asked to circle or point to the sentence he thought was “not good” and then explain why he thought it was not a grammatical sentence. This task had two parts; each part was administered at a different session. The first part of the task included sentences with verb movement; the ungrammatical sentences were sentences in which the antecedent also appeared in the canonical argument position (a resumptive NP instead of a gap) (as in example 11). Both sentences included the same verbs and participants. In the second part of the task both sentences had the same sentence structure, but the verb and the verb complements were synonyms and not matched in gender (example 12).

(11) Example items part 1

a. (grammatical)

הרמתי את הכלבה שסבתא הביאה

Heramti et ha'kalba she'safta heviah

I picked up the dog that grandma brought

b. (ungrammatical)

הרמתי את הכלבה שסבתא הביאה ***את הכלבה***

Heramti et ha'kalba she'safta heviah ***et ha'kalba***

I picked up the dog that grandma brought ***the dog***

(12) Example items part 2

a. (grammatical)

זה **הארגז** עם המכסה שהאישה הקשישה שמרה בתוכו את הבגדים הישנים

This is the box (m) with the lid that the old lady kept old clothes in it (m)

b. (ungrammatical)

זו **התיבה** עם המכסה שהאישה הקשישה שמרה בתוכו את בגדים הישנים.

This is the chest (f) with the lid that the old lady kept old clothes in ***it (f)***

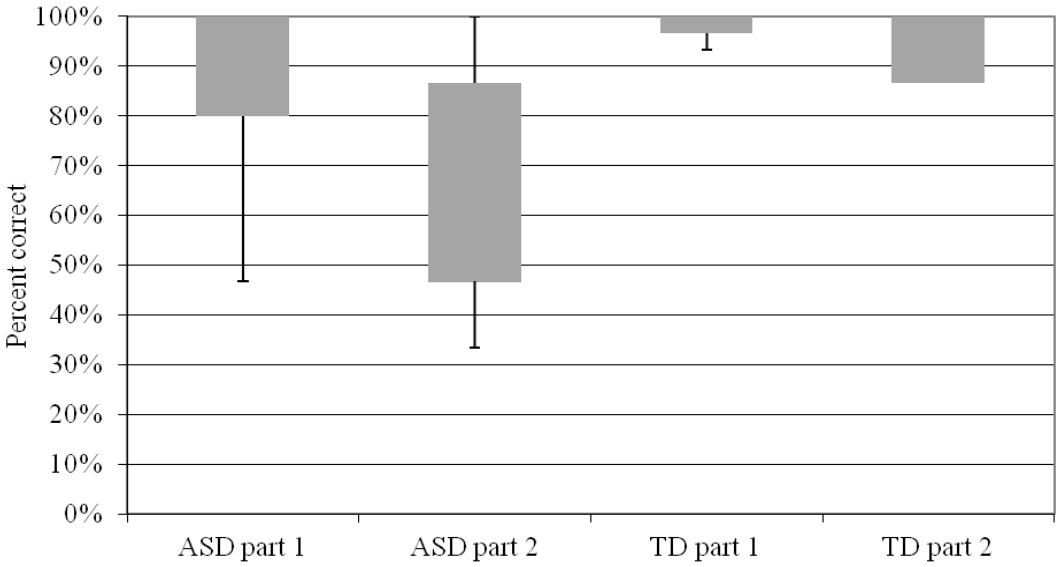
Correct answers were counted for each part and participants' explanations for ungrammaticality were analyzed. If the participant refused to cooperate, refused to choose a sentence, or choose only sentences that appeared on a certain side of the page for five consecutive trails, the testing of this task was stopped.

The control group for this task included the same TD children described in Section 7.1.1 (n = 11).

7.9.2 Pronoun agreement judgment: group results

The aim of this task was to test if participants are able to identify ungrammatical sentences and explain why they are so. The control group participants who were the same age as the youngest ASD participants were all able to understand and complete the task. They performed significantly better than the ASD participants (TD group global scores: *M* = 94%, *SD* = 6, range – 80-100%; ASD group global scores: *n* = 28, *M* = 71%, *SD* = 25, range = 43-100%; *t* (27) = 2.64, *p* = .013). In the ASD group, scores varied widely; some participants (*n* = 10) were unable to complete the task, some had significantly lower scores than the TD group, and some scored at ceiling levels. Distribution of ASD correct scores is shown in figure 18.

Figure 18. Pronoun agreement judgment (percent correct): ASD and TD



Part one of the task included sentences with verb movement in which the antecedent after the trace appeared again, and part two of the task included sentences with verb movement wherein the verb and verb compliments were synonyms and unmatched in gender. In both groups a significant difference was found between the parts, with scores being higher on the first part (TD: *t* (10) = 2.89, *p* = .008; ASD: *t*

(27) = 4.35, p = .0001). In the ASD group, ten participants had significantly lower scores than the TD group on both parts of the task. Four participants had significantly lower scores than the TD group only on the first part of the task and finally three participants had significantly lower scores than the TD group only on the second part of the task.

TD participants in most cases were able to explain why the sentence was incorrect (ex. 'this word at the end of the sentence shouldn't be there, it doesn't sound right'). Most of the ASD participants on the other hand either stated that the sentence "can't be" or that they didn't know the reason for it being wrong (even if they choose the correct answer).

In conclusion, scores in the ASD group varied widely and most ASD participants were unable to explain their answers. Moreover, a large group of ASD participants was unable to complete the task due to misunderstanding of the task demands.

7.9.3 Plausibility judgment: task description

This task was built for this research. The aim of the task was to test the possible influence of syntax on semantic comprehension and vice versa. Each participant was shown a sentence on an A4 sheet of white paper and was asked to say if this sentence "could be true" or not. If the participant answered negatively, he was asked to explain why not. If the participant had good reading abilities (as assessed by the Tiltan word reading task), he was asked to read the sentence; if not the sentence was read to him. If it seemed that because of incorrect reading the participant misunderstood the sentence, it was read to him. The task consisted of six different sentence types – each type having six pairs of plausible and implausible sentences. The sentence types matched the sentence types that appeared in the repetition task so

that it would be possible to control the participant's comprehension and production. Sentence types included:

(13) Simple sentences

אתמול הילד חבש את הכובע

Etmol ha'yeled chavash et ha'kova

'Yesterday the boy put on the hat'

(14) Sentences with verb movement

אתמול הסירה שטה בילדה

Etmol ha'sira shata ba'yalda

'Yesterday the boat sailed in the girl'

(15) Embedded sentences

הכלבה אמרה שהילדה רעבה

Ha'kalba amra she'ha'yalda reeva

'The dog (f) said that the girl is hungry'

(16) Sentences with Accusative movement

אתמול הרטיב האיש את הגשם

Etmol hertiv ha'ish et ha'geshem

'Yesterday the man wet the rain'

(17) Sentences with WH movement

את איזה מורה התפוח אכל?

Et aize morah ha'tapuach achal?

'Which teacher did the apple eat?'

(18) Implausible simple sentences

זה התות שאהב לרקוד

Ze ha'tout she'ahav lirkod

This is the strawberry that loved to dance

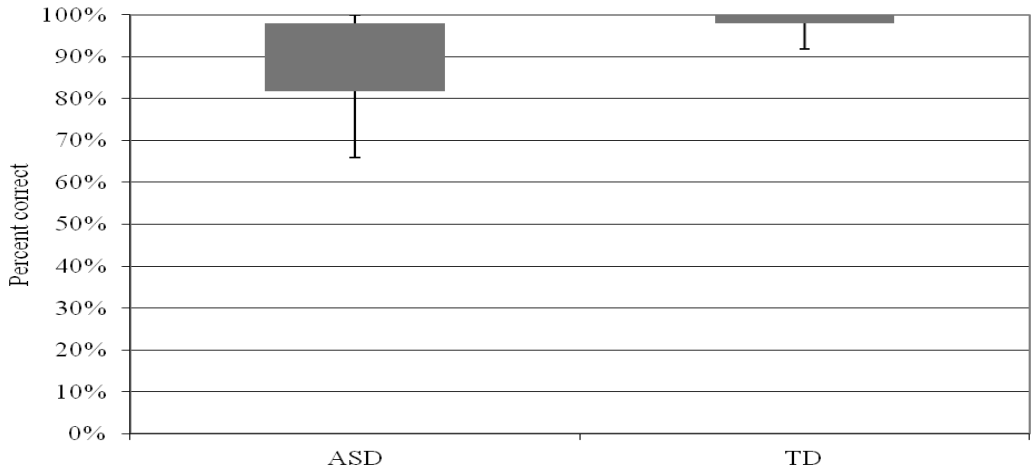
The task was administered during two different sessions, each session containing only one sentence of each pair. For each participant the number of correct answers was counted and the explanations of why a sentence was not plausible were analyzed. There were participants who did not understand the task demands, or if for five consecutive sentences the participant said it was correct (or not, but could not explain), testing of the task was stopped.

The control group for this task was the same as that described in Section 7.1.1.

7.9.4 Plausibility judgment – group results

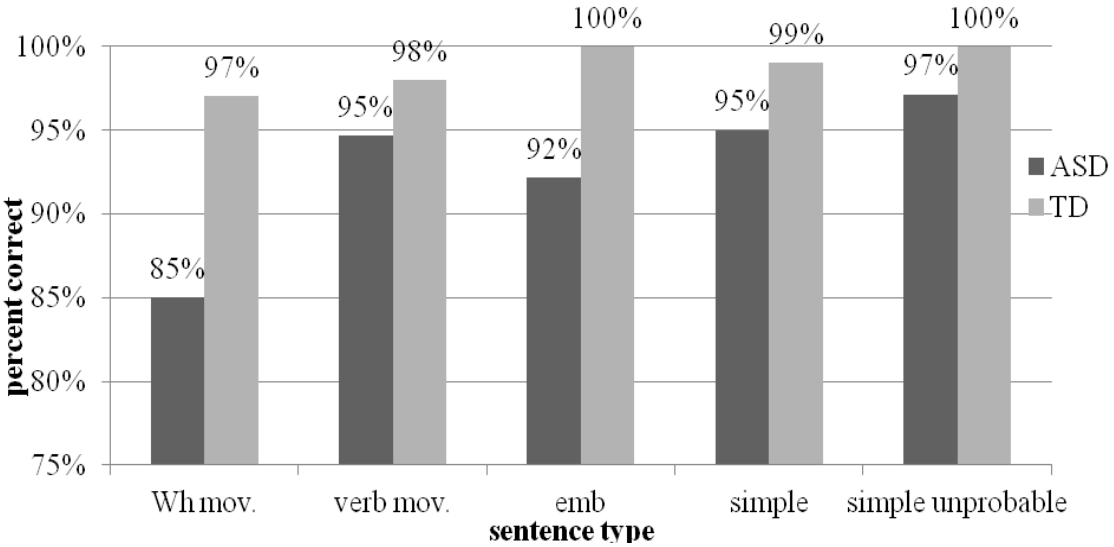
Participants from both groups found this task funny and cooperated regardless of their performance. The control group participants (who were younger than the majority of the ASD participants) scored at ceiling levels on all sentence structures; their performance was significantly better than that of the ASD participants (TD group: M = 98%, SD = 3, range = 92-100%; ASD Group: n = 28, M = 90%, SD = 10, range = 66-100%; t (27) = 4.26, p = .004). In the ASD group, eight participants were unable to complete the task due to not understanding the task demands while others completed the task easily. The variability of scores was very big as shown in Figure 19.

Figure 19. Plausibility judgment (percent correct): ASD and TD



Ten out of the 28 participants who completed the task had significantly lower scores than the control group and, as a group, the lowest scores were found on sentences with WH movement and verb movement, as shown in Figure 20. Control group participants scored at ceiling levels on all sentence types and significantly better than the ASD group on sentences with WH-movement and embedded sentences.

Figure 20. Plausability judgment by sentence type (percent correct): ASD and TD



In summary, although as a group scores were lower than those of the control group, the ASD scores were high enough to show that they understood the task demands and in most cases understood most of the syntactic structures tested. Specific problems will be discussed in the next chapter, on individual results.

7.10 Tasks testing the Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological input buffer and lexicon, semantic lexicon and conceptual system

7.10.1 Comprehension of mental verbs: task description

This task was taken from the study by Eilon (2013). The aim of the current task was to test the participant's ability to understand the mental or emotional state of a character from a short story based on the character's behavior. This task tested whether the participant was able to judge and access the semantic properties of emotions based on a story and whether he could match a label to those emotions and mental states.

Participants were shown a short printed story that was read aloud by the experimenter. At the end of the story the participant was shown three options of mental verbs that could complete the last sentence starting with a description of the mental or emotional behavior of the character. Participants were asked to choose the most correct option. The first story was an example to make sure participants understood the task and was not counted in answer analysis. The task included twelve short stories (six depicting a mental state (ex. imagining), six depicting an emotional state (ex. fear) and six depicting a physical activity (ex. playing). The latter served to control that the subject understood the task.). Answer analysis was done according to Eilon (2013) wherein each item answered correctly was given a point, giving a maximum of six points for each part.

(19) Example item, comprehenshion of mental verbs

Gadi is going to a new school today. He woke up early, changed his shirt twice and didn't eat anything before leaving the house. What is the most appropriate thing to say about Gadi? Gadi is…

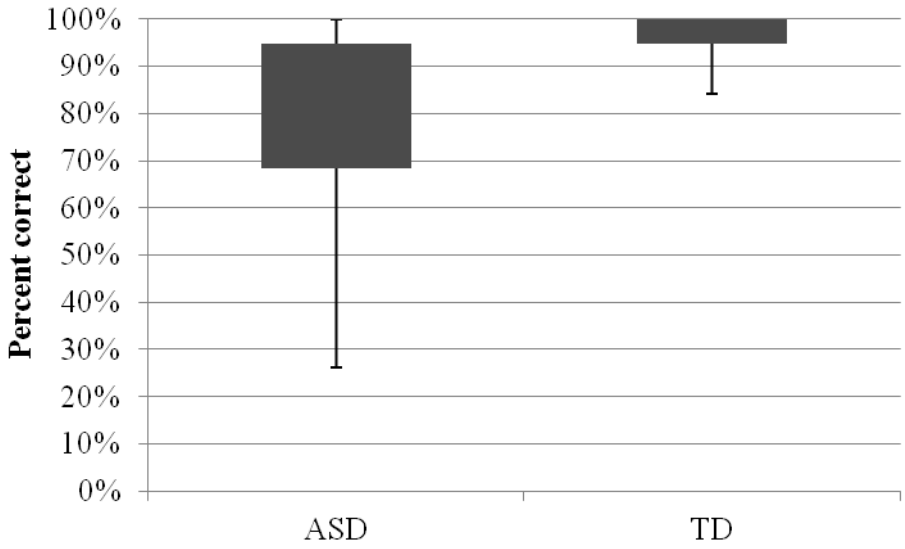
1. excited, 2. thinking, 3. in a hurry

The control group for this task had the same participants as those described in Section 7.1.1.

7.10.2 Comprehension of mental verbs – group results

The TD participants in this task (all in 3rd grade) were all able to read the story themselves and answer the questions at ceiling levels. In the ASD group, most of the participants were able to complete the task (n = 34), those with low reading scores (as seen in the Tiltan reading test), were read the story along with the written presentation of it. The ASD group variance was very big and a significant difference between the two groups was found (TD group: n = 16, M = 97%, SD = 2, range = 95-100%; ASD group: n = 34, M = 79%, SD = 20, range = 26-100%). Twenty-four ASD participants had scores that were significantly lower than the control group (cutoff score: 88%; t (15) = 1.94, p = .036). Both groups scored significantly better on the physical verbs compared to the mental verbs (TD: t(15) = 2.78, p = .007; ASD: t(33) = -5.24, p < .0001), the ASD group (not TD) scored significantly better on the emotional verbs compared to the mental verbs (TD: t(15) = 1.00, p = .17; ASD: t(33) = 3.86, p = .0002), and finally the TD group (not ASD) scored significantly better on the physical verbs compared to the emotional verbs (TD: t(15) = -2.24, p = .021; ASD: t(33) = 1.44, p = .08).

Figure 21. Comprehension of mental verbs (percent correct): ASD and TD



In conclusion, it seems that most ASD participants struggled with the mental verbs on this task, while achieving better scores on the emotional and physical verbs.

7.11. Tasks testing the Orthographic-visual analysis and orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer as well as semantics and syntax

7.11.1 Reading and paraphrasing of relative clauses with an embedded heterophonic homograph: task description

This task was taken from the study by Friedmann & Gvion, (2003) to test whether participants access their semantic component while reading and whether the structure of the sentence will influence their understanding and so influence their reading of the heterophonic homograph.

After reading the sentence the participant was asked to explain it in his own words. This was done in order to test what the participant had understood from the text and to see if the participant was able to access the information he had just read.

The task included 20 sentences with a central verb that is a heterophonic homograph of a noun. Each one of the ten homographs appeared in two sentences –

once in a sentence with a relative clause and once in a simple sentence with no verb movement, but having the same number of words. The relative clause sentences were object relative sentences with central embedding, where the homograph appeared as a verb at the position right after the trace. Example (20) shows a relative clause sentence with the homograph "g-z-r" which can be read as a verb "gazar" = cut, or as a noun "gezer"=carrot. Example (X) shows the same homograph in a control sentence.

(20) Relative clause sentences with the homograph "g-z-r"

Ha'bachur sh'ha'yeled ahav gazar itonim yeshanim

'The guy that the boy loved cut old newspapers'

(21) simple sentence with the homograph "g-z-r"

Ha'yeled mi kita daled gazar itoni sport

'The boy from 4th grade cut sports newspapers'

The test sentences were split into two parts; each part was administered at a different session. Each part included ten sentences, five relative clauses and five simple sentences. In each part, each homograph appeared only once, either in a simple sentence or a relative clause.

The participants were shown the ten sentences on a printed A4 page and asked to read each sentence aloud and then explain it in their own words. Subjects who had difficulties reading were shown only one sentence at a time. If the subject was unable to explain the sentence in his own words, leading questions were asked (who were the characters in the sentence, what were they doing?). Correct responses were counted for correct reading of the homograph and quantitative analysis was done on the paraphrasing part. Participants who were unable to complete the Tiltan reading test were not administered this task (n = 8). The control group for this study contained the

same group of children described in Section 7.1.1 as well as a group of 10- to 18-year-old typically developing children (n = 18, M age = 13, SD = 2.3) that had been participating in other studies at the Language and Brain lab at Tel Aviv University. The age range of the second control group was very wide, but since no significant difference was seen in any of their scores they were treated as one group.

7.11.2 Reading and paraphrasing of relative clauses with an embedded heterophonic homograph: group results

This task had two components: reading and paraphrasing and in both components simple sentences versus object relative clauses were used. The older TD participants scored at ceiling levels on all parts and no significant difference was found between sentence types. The younger control group seemed to have more trouble reading the homographs in sentences with relative clauses and some participants seemed to not understand the task demands of paraphrasing a sentence. A significant difference between the younger TD group and younger ASD group was found only on paraphrasing of relative clause sentences, but this result should be interperated with caution as the number of ASD participants in this group was small. In the older TD group and older ASD group, a significant difference between the groups was found on all sentence types both in reading the homograph and in paraphrasing the sentences.

Table 6. Reading and paraphrasing: group characteristics and percent correct

	Homograph reading				Paraphrasing			
	Simple sentences		Relative clause sentences		Simple sentences		Relative clause sentences	
	TD	ASD	TD	ASD	TD	ASD	TD	ASD
3rd grade (8-9 years old)	0.94 (0.06)	0.85 (0.104)	0.88 (0.11)	0.70 (0.21)	0.66 (0.32)	0.67 (0.33)	0.59 (0.31)	0.32 (0.23)
N Participants	14	6	14	6	14	6	14	6
TD vs. ASD	t (5)= -1.39 *p* = .1121		t (5)= -2.00 *p* = .0510		t (5)= -0.39 *p* = .357		t (5)= -2.35 *p* = .033*	
N ASD Participants below TD	*n* = 3		*n* = 4		*n* = 5		*n* = 6	
10- 18 years old	0.99 (0.03)	0.80 (0.15)	0.99 (0.03)	0.94 (0.09)	0.99 (0.02)	0.48 (0.36)	0.97 (0.06)	0.66 (0.34)
N Participants	18	29	18	29	18	29	18	29
TD vs. ASD	t (23)= -1.86 *p* = .0413*		t (23)= -5.0, *p* = .0001*		t (23)= -4.25 *p* = .0003*		t (23)= -6.0 *p* < .0001*	
N ASD Participants below TD	*n* = 8		*n* = 17		*n* = 18		*n* = 21	

In the ASD group, age seemed to be a factor in performance. Nine children were compared to the younger TD control group (ASD children aged 8;1-9;11 years). Out of these, three were unable to complete the task either due to poor reading capabilities or not understanding the task demands. ASD scores compared to controls presented in Table seven.

Table 7. Reading and paraphrasing: ASD performance compared to control groups

	Homograph reading		Paraphrasing	
	Simple sentences	Relative clause sentences	Simple sentences	Relative clause sentences
3rd grade (8-9 years old) TD: n = 14 ASD: *n* = 6	Cut off score 0.83 TD-ASD comparison : t (13) = -1.771, *p*=.049 3 ASD significantly lower.	Cut off score 0.67 TD-ASD comparison : t (13) = -1.844, *p*=.044 1 ASD significantly lower.	Cut off score 0 TD-ASD comparison : t (13) = -1.839, *p*=.044 3 ASD significantly lower.	Cut off score 0 TD-ASD comparison : t (13) = -1.993, *p*=.033 3 ASD significantly lower.
10 - 18 years old TD: n = 18 ASD = 29	Cut off score 0.93 TD-ASD comparison : t (17) = -1.947, *p*=.0341 17 ASD significantly lower.	Cut off score 0.93 TD-ASD comparison : t (17) = -1.947, *p*=.0341 8 ASD significantly lower.	Cut off score 0.95 TD-ASD comparison : t (17) = -1.947, *p*=.0345 18 ASD significantly lower.	Cut off score 0.86 TD-ASD comparison : t (17) = -1.84, *p*=.046 21 ASD significantly lower.

In the older group (ASD participants aged 10-18 years old), 29 participants were included, out of these 5 were unable to complete the task. Most of the ASD participants in this group had significantly lower scores as compared to controls on reading sentences with a relative clause and paraphrasing both sentence types.

In both groups, in all cases when the homograph was read incorrectly it was read as the wrong pronunciation of the noun, no nonword productions or words that were not related to the target word were produced. In the control group, when a paraphrasing error was made, it mostly included repeating the original sentence or paraphrasing the sentence with reversed roles of the NP's. In addition to these error types, the ASD participants also produced paraphrasing errors in which either one of

the NP's or the verb was omitted or information not present in the original sentence was added. Individual error patterns will be presented in the next section.

In summary, the task demands were hard for the ASD participants as well as for the younger TD participants. Reading and comprehending sentences with a center embedded object relative clause seems to be problematic for a significant group of children with ASD.

7.11.3 Reading of sentences with a two meaning heterophonic homograph: task description

This task was part of a study by Sukenik (2012). The task was built based on a task used by Frith and Snowling (1983). As in Frith and Snowling's original study, the homograph appeared towards the end of the sentence, after the disambiguating context. Participants were asked to read heterophonic homographs that were incorporated in sentences that biased their meaning towards only one reading. The sentences were all simple sentences and the hetrophonic homographs that were used were all noun-noun homographs whose correct reading meant that the participant had to understand the meaning of the sentence and the meaning of the word that would most likely be relevant to the context. Thirteen noun-noun heterophonic homographs were each incorporated into two sentences such that only one interpretation was semantically acceptable. Importantly, there were no syntactic cues to the appropriate pronunciation of the homograph. The example below shows the English gloss of two sentences presented with the homograph ,קופה which can be read as either *kupa*, meaning 'cashier'', or *kofa*, meaning (female) 'monkey':

(22) Two possible ways to read the homograph "k-p-h"

a. In the mall, mom bought a dress and she had to pay, so she looked for a **cashier**.

b. In the zoo, the guide showed everyone a giraffe and a zebra and then she also found a sweet **monkey**.

Test sentences were divided into two parts and administered on different sessions, with each homograph appearing once in each part to minimize potential interference effects (cf. Brock & Bzishvili, 2013). The participants were asked to read the sentences aloud with no time limits.

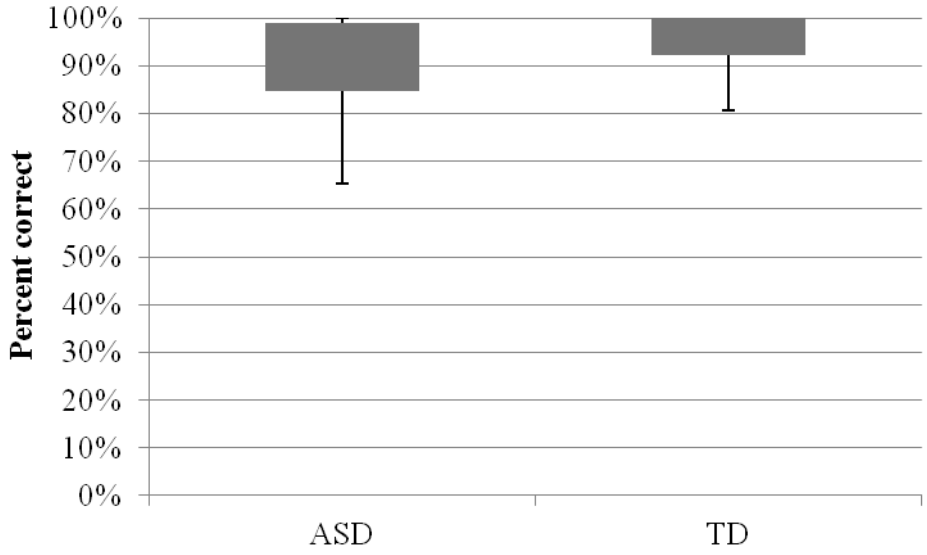
Correct reading of the homographs was counted for each participant. Participants who were unable to complete the Tiltan reading test were not administered this task.

The control group for this task consisted of 21 TD children, nearly half (n=10) were studying in 4th grade, while the others (n = 12) were studying in 3rd grade. Control group data were collected as part of the study by Sukenik (2012). No differences were seen between groups and so they were treated as one group (*mean age* = 9.5; *SD* = 0.2).

7.11.4 Reading of sentences with a two meaning noun homograph – group results

The mean scores of both the control group and the ASD group were not significantly different although, the variance of responses in the ASD group was much wider than that of the controls (TD group: n = 22, M = 95%, SD = 6, range = 81- 100%; ASD group: n = 30, M = 90%, SD = 10, range = 65 –100%; $t(35) = 0.75$, p = .23).

Figure 22. Semantic homograph reading (percent correct): ASD and TD



In both groups, when an error was made, it consisted of reading the homograph as the word which is perceived to be the most common interpretation. In the TD group in many cases the participants corrected themselves, while in the ASD group this was not very common.

These results show that as a group, most ASD participants do use context to interpret the meaning of words as they were able to use the context of the sentence to produce the correct form of the homograph.

7.11.5 Word definition: task description

This task was adapted from the study by Friedmann, Aram & Novogrodsky, (2011). The purpose of this task was to examine the participant's level of understanding of a single word and their ability to produce explanations regarding these words. In order to produce an explanation the participant would have to correctly access the word's meaning and produce a sentence that explained its semantic properties. Each participant was presented with a single word on a computer screen. The participant was asked to read the word aloud and then explain its meaning. Participants were presented with 30 words including nouns, verbs and

emotions. The participants were asked to say what the meaning of the word they read was. Word order was fixed. Answer analysis was done according to the definition provided to determine whether the participant understood the meaning of the word, whether the definition was pragmatically appropriate (i.e., whether another person could understand what the word in question was) and whether the participants understood the target word. Participants who did not complete the Tiltan reading test were shown the words on the screen and the word was read to them.

The control group participants were the same as those described in Section 7.1.1.

7.11.6 Word definition – group results

Out of the 38 ASD participants, three that did not complete the Tiltan reading test were read the words and were able to define them. The control group participants had ceiling level scores on all three variables tested: reading of the word, understanding of the word and producing a pragmatic answer and so a score was considered significantly different/ impaired in the ASD group if a participant made two or more errors. The ASD and TD group scores are presented in Table 8.

Table 8. Definition task: group characteristics and M percent correct

	Reading the word	Understanding the word	Producing a pragmatic answer
TD (*n* = 9)	*M* = 100%, *SD* = 0	*M* = 100%, *SD* = 0	*M* = 99%, *SD* = 3
ASD (*n* = 38)	*M* = 89%, *SD* = 28	*M* = 96%, *SD* = 16	*M* = 65%, *SD* = 31
TD/ASD Comparison	t (37) = -1.51 *p* = .084	t (37) = -1.00 *p* = .1733	t (37) = -4.30 *p* = .0013

All TD participants used relative clauses in most of their definitions (ex. "house" – A place where people live). In the ASD group on the other hand the use of relative clauses was scarce (mean use of relative clause as definition (out of 20) M = 11.5, SD = 7.2), ex. "bed" – sleeping.) Individual performance and errors will be discussed in the next chapter.

Out of the twenty words presented to the participants, four were abstract words (vegetables, dressed, wrote, happiness). The TD group didn't show any significant difference in their performance on these words compared to the more concrete words. In the ASD group, a significant difference was found in favor of the concrete words ($t(32) = -2.76$, $p = .0048$). Out of the 38 participants who completed the task, 16 were found to perform significantly better on the concrete words than on the abstract words ($p < .005$).

Summarizing, this task was one of the tasks that all 38 ASD participants were able to complete. All were able to understand most of the words presented but their definitions were productions of sentences that in most cases were not age appropriate. The nature of the target word (abstract vs concrete) seemed to influence performance.

8. Modality of tasks

One of the ongoing debates in autism research is to what extent the nature and demands of a task influence the results of participants with ASD. This study tested linguistic abilities in a range of modalities and group results were compared between them. On tasks that had more than one score (reading and paraphrasing for example, a composite score was calculated based on the mean of all subtests). Task modality could not be compared in the control participants, as all tasks did not have the same control participants.

8.1 Explicit versus implicit tasks

Based on previous research that found contradicting results regarding the semantic performance of participants with ASD, one of this study's hypotheses was that the more explicitly the task demands are about the need to access the semantic component, the more likely that children with ASD will have better performance. Tasks were divided into four categories based on how explicitly access to the semantic component (meaning) was part of the task demands as shown in Table nine. Tasks for which task demands did not make it possible to distinguish between these categories were not included in this analysis.

Table 9. Explicit and implicit task categorization

Most explicit			Most implicit
1. Meaning of single words	2. Meaning of more than one word and comparing semantic representations	3. Comparing two semantic representations within a sentence structure.	4. Sentence semantics.
Picture naming Single word definition	Written word – picture matching Odd one out pictures and words Picture association and word association (Pyramids and Palm trees)	Plausibility judgment Mental verb comprehension Sentence comprehension- Similar semantic/ phonological NP Word Association (Ma Kashur)	Reading and paraphrasing of relative clauses with a heterophonic homograph Sentence reading with a noun homograph Pronoun agreement judgment Sentence picture matching – sentences with different precursor and trace differences Sentence repetition Word memory

For each these four categories (most explicit, somewhat explicit, somewhat implicit, and most implicit), a composite score was calculated based on the average of scores of all tasks in that category. Composite scores of all ASD participants were

then compared using a t-test in order to see if a significant difference was found between categories (Table 10).

Table 10. Differential performance on explicit and implicit tasks in ASD group

X	1. Meaning of single words	2. Meaning of more than one word and comparing semantic representations.	3. Comparing two semantic representations within a sentence structure.	4. Sentence semantics.
1. Meaning of single words		$t(37) = 5.94$, $p < .0001$	$t(37) = 8.43$, $p < .0001$	$t(37) = 7.29$, $p < .0001$
2. Meaning of more than one word and comparing semantic representations.			$t(37) = 5.90$, $p < .0001$	$t(37) = 3.70$, $p = .0004$
3. Comparing two semantic representations within a sentence structure.				$t(33) = -3.35$, $p = .0011$

A significant difference was found between the first category (most explicit) and the three other categories, showing that scores were indeed higher on tasks entailing explicit access. A significant difference was also found between category two and three and between category two and four, again pointing to the fact that the more explicit the task the higher the scores achieved. Category three was found to have higher scores than category four, but this may be due to other task properties as described in the next section.

8.2 Task properties

The first comparison was of the way a task was administered, a stimulus was either presented on a computer screen or on an A4 paper. Seven tasks were tasks that were administered using paper only (Association task -Pyramids and palm trees – picture and word part, Semantic homograph reading, Mental verb comprehension, Probability judgment, Pronoun agreement judgment and Reading and paraphrasing of relative clauses with a hetrophonic homograph) and seven more tasks were administered on a computer screen (Picture naming, Word Association (Ma Kashur), Word picture matching, Odd one out picture and word part, Sentence picture matching, and Definition). No significant differences between task presentations were found on group performance for either the ASD group or the control groups ($t(6) = 0.76$, $p = .24$; $t(6) = 1.00$, $p = .18$, respectively).

Next, tasks that were presented with pictures (Picture naming, Word-picture matching, Association -Pyramids and palm trees- pictures, Odd one out pictures and Sentence picture matching), involved reading (Word association -Ma Kashur-, Association -Pyramids and plam trees-words, Odd-one-out words, Semantic homographs reading, Mental verb comprehension, Definition, Probability judgment, Pronoun agreement judgment and Reading and paraphrasing of relative clauses with a hetrophonic homograph) or were presented only auditory (Sentence comprehension - Meguvana, Sentence repetition and Semantic phonological word memory) were compared. In the TD groups, no significant difference was found between the different task types (Picture / Reading $t(4) = 1.00$, $p = .19$; Picture / Auditory $t(4) = 1.00$, $p = .19$; Reading / Auditory $t(8) = 0.51$, $p = .32$). In the ASD group, no significant difference was found between the picture tasks and the reading tasks ($t(4) = 1.96$, $p = .06$), but the ASD group did significantly better on tasks with pictures

compared to orally presented tasks ($t(4) = 5.03$, $p = .008$) and better on tasks that involved reading compared to orally presented tasks ($t(8) = 2.89$, $p = .03$).

The final comparison was between items that were abstract versus items that were concrete. In the concrete items we included specific words from the Tiltan reading test (guy, shoelace, cheese, corn etc.), specific words from the Definition task (house, bed, telephone etc.), and specific words from the Word association -Ma Kashur task (chocolate, book, pencil, etc), and the concrete words from the word association -Pyramids and palm trees task. The sum of correct answers for these words was used as a score for this sub part of the task. We also used the global score of the following tasks: Odd one out picture task, the Picture association -Pyrmids and plam trees task, the naming task, the word picture matching task and the sentence picture matching task. In the Abstract items we included specific words from the Tiltan reading test (where, maybe, excited etc.), specific words from the Definition task (vegetables, happy etc.), and specific words from the Word association task -Ma Kashur task (sea, quiet, family etc) and the abstract words from the Word association -Pyramids and plam trees task. As well as the global score of the following tasks: Odd one out words task and sentence comprehension task. A comparison was done between all tasks assessing concrete versus abstract as well as inter task comparison of the different items.

Out of the 38 ASD participants, 7 had not completed enough tasks for the comparison to be made statistically. On the tasks tested, six ASD participants had a significant difference ($p < .005$) in favour of concrete items over abstract ones. Although the remaining 25 participants did not have a significant difference between tasks, all showed a significant difference on at least one inter-task comparison.

In summary, it seems like the way in which a task was presented, explicit versus implicit, has a big effect on the participants' scores while task properties (paper versus computer) didn't have an effect on performance in children with ASD. Whether the task involved pictures, reading or auditory stimuli seems to have an effect on group results. Conclusions regarding abstract versus concrete items are hard to make as these were not controlled for when building the tasks. Results suggest that future studies could profitably test this point more thoroughly.

8.3 Background measures

This study had two background measure tasks: RPM (a measure of NVIQ) and the CCC (a measure of pragmatics). In order to test if one of these (as well as age) was related to any of the other linguistic tasks, we used Pearson's correlation.

Examining first of all Age, RPM and CCC standard scores, a bivariate correlational analysis found that age and RPM standard scores were related to each other (r = .37, n = 31, p = .043), but that age and CCC score were not (r = ..270, n = 38, p = .101). Importantly, a moderately strong link was found between RPM scores and CCC pragmatic composite scores (r = .63, n = 31, p < .001). In order to determine any link between RPM/CCC-pragmatics and our 16 experimental tasks, we used partial correlations with age and either RPM or CCC-pragmatics as covariates.

Controlled for age and CCC-pragmatics, RPM was correlated only with the Tiltan nonword reading task (r = .45, n = 18, p = .049). Finally, controlling for age and RPM, it was found that the CCC-pragmatics was correlated with four tasks: Word association task (r = .59, n = 18, p = .007), Semantic-Syntactic reactivation sentence picture matching (r = .53, n = 18, p = .016), Mental verb comprehension (r = .511, n = 18, p = .021) and Odd one out words (r = .50, n = 18, p = .025).

Summary group results

As a group, the ASD group scored lower than the control groups on all tasks in this study, as is summarized in Table 11. Individual differences were very big and so group conclusions need to be addressed with caution. It seems that the majority of the ASD group are able to complete tasks with pictures and tasks that tap more exclusively into the conceptual and semantic components. Reading scores varied widely, with floor and ceiling scores across the group. Nonverbal IQ (RPM) or CCC-pragmatics did not seem to be a significant factor in performance.

Table 11. ASD group score summary

		N Participants who completed task (/ 38)	Group mean (*SD*)	*Range*	*N (%) below cutoff score*
1.	Odd one out (picture part)	36	90% (0.79)	71 – 100%	12 (33%)
	Odd one out (word part)	30	79% (0.18)	25-100%	19 (63%)
2.	Association task - Pyramids and palm trees (pictures part)	36	97% (0.04)	84-100%	3 (8%)
	Association task - Pyramids and palm trees (words part)	30	85% (0.13)	49-100%	24 (80%)
3.	Semantic phonological word memory – "Probe"	23	71% (0.14)	46-94%	6 (26%)
4.	Sentence repetition task - "Petel"	31	73% (0.23)	3-99%	23 (74%)
5.	Sentence comprehension- Similar semantic/ phonological NP – "Meguvana"	32	64% (0.16)	31-94%	18(56%)
6.	Semantic-syntactic reactivation sentence-picture matching – "Mekayim"	31	82% (0.13)	57-100%	19 (61%)
7.	Pronoun agreement judgment	28	71% (0.25)	43-100%	16 (57%)
8.	Plausibility judgment	28	90% (0.10)	66-100%	10 (35%)
9.	Word Picture matching – "Pilpel"	38	90% (0.09)	60-100%	19 (50%)
.10	Word association task – Ma Kashur	30	87% (0.13)	55-100%	6 (20%)
11.	Comprehension of mental verbs	34	79% (0.20)	26-100%	24 (70%)
12.	Reading test - Tiltan single words	31	88% (0.10)	60-100%	13 (41%)
	Reading test - Tiltan pairs	31	93% (0.08)	67-100%	7 (22%)
	Reading test – Tiltan (non-words)	31	92% (0.07)	75-100%	3 (9%)
13.	Reading and paraphrasing of relative clauses with a heterophonic homograph – homograph reading	35	85% (0.12)	60-100%	20 (57%)
	Reading and paraphrasing of relative clauses with a heterophonic homograph – paraphrasing	35	56% (0.30)	0-100%	24 (68%)
14.	Reading of sentences with a two meaning noun homograph	30	90% (0.10)	65-100%	10 (33%)
15.	Word definition – correct reading	37	89% (28)	0-100%	5 (13%)
	Word definition – correct understanding	37	96% (0.16)	90-100%	0
	Word definition – pragmatic answer	37	65% (0.31)	0-100%	24 (64%)
16.	Picture naming "Shemesh"	38	91% (0.08)	66-100%	10 (26%)

9. Individual Profiles

9.1 Introduction

Each of the tasks in this study was selected to assess different kinds of linguistic competences and to identify different types of impairment. In the following chapter the individual results of the ASD group will be presented. As with most studies on children with ASD, group conclusions are hard to make and in order to see the full picture one has to take a closer look at the linguistic profile of each individual in the group.

To create the linguistic profile of each ASD participant, we established, for each task and each condition, the threshold below which the performance is already significantly below that of the control group. We did so by the comparison of each individual in each task and condition, to the performance of the control group in that task and condition, using Crawford et al., t-test (2010). This allowed us to establish for each individual with ASD, if the performance was impaired compared to the control group. On some tasks, control group performance was at ceiling levels and there was no variation, in such case we used an arbitrary threshold for impairment of performance below 90%. (i.e., ASD individual scores of 90% correct and above were considered to be indicative of unimpaired performance, even if statistically lower than TD performance). In addition to overall accuracy scores, for each task, a qualitative error analysis was done based on the task demands and individual responses.

In order to build individual profiles, each participant's performance was investigated by looking at all tasks testing each component. For example, two tasks tested the conceptual component (the odd-one-out pictures and Picture association Pyramids and plam trees tasks). The scores as well as the error analysis of both tasks

were analyzed and a conclusion was drawn regarding whether the child displayed intact or impaired performance for this component. When scores on both tasks were consistent and age equivalent, reaching conclusions was simple. When performance on one task (but not the other) was lower than control group performance, we made an in depth error analysis to determine whether low performance was a result of an impaired component or other variables such as lack of cooperation. In these cases, we also looked at the performance of that participant on related tasks, which also involve the relevant component. For example, if a participant achieved a low score on one of the tasks testing the conceptual component (but was good on the other), we looked at other tasks that required a well-functioning conceptual abilities, such as picture naming and word-picture matching. If the participant had ceiling scores on the Picture naming task and the Word-picture matching task, we concluded that his conceptual component was intact. In the following sections we will present the results of these individual profiles.The tables presenting the individual scores will present most tasks but a description of the tasks analyzed qualitatively will be presented separately in cases when these are relevant.

Table 12. Location of impairment: ASD participants[2]

Participant	Conceptual impairment	Semantic lexicon impairment	Impaired access to the semantic lexicon	Impairment in the phonological output lexicon	Syntactic impairment : WH/CP/ALL	Reading deficit LPD// sublexical/ surface	Phonological input memory impairment
TE	v	v	x	V	ALL	v	v
YA	v	v	v	X	ALL *[3]	v	v
AM	v	v	v	V	ALL	v	v
SZ	v	v	x	V	WH	v	v
ID	v	x	x	X	ALL	x	x
SA	v	x	v	V	WH	Surface and attention	v
NA	v	x	v	X	ALL*	v	v
MA	v	v	v	V	WH	v	v
IC	v	x	v	V	WH	LPD maybe surface	v
SH	v	x	v	V		LPD	v
SC	v	v	v	V	WH	v	v
SB	v	v	v	X	Auditory access to syntax	v	x
DA	v	x	v	X	WH	v	v
YR	v	v	v	V	WH	v	v
RO	v	x	v	V	ALL	v	v
BA	v	x	v	V	*	v	v
MI	v	v	v	V	ALL	v	v
YO	v	x	v	V	ALL	v	v
TP	v	v	v	V	v	v	v
YU	v	v	v	X	WH	LPD	v
AL	v	v	v	V	v	v	v
AD	v	v	v	V	CP	v	v
PE	v	x	v	V	WH	v	v
TY	v	v	v	V	v	Inter lexical deficit	v
YM	v	v	x	V	ALL	v	v
TZ	v	v	v	V	Control	v	x

[2] x = found to be impaired; v = found to be intact

[3] Starred participants are participants who were LFA and didn't complete the syntactic tasks. Their syntactic impairment was evident in the Definition task and therefore we cannot tell the exact depth of the deficit.

AR	v	v	v	V	WH	v	v
GA	v	v	v	V	WH	v	v
YC	v	v	v	V	v	v	v
IT	v	v	v	V	WH	v	v
OO	v	x	v	V	*	LPD	v
OM	v	v	v	V	WH	v	v
MO	v	v	v	V	WH	Surface and Vowel letter	x
AT	v	v	v	V	WH	v	v
PT	v	v	v	V	v	v	v
SK	v	v	v	V	Auditory access to syntax	v	v
OF	v	x	v	V	*	v	v
NG	v	v	v	V	WH	v	v

Section 9.1 presents an introduction to this chapter. Section 9.2 presents the ASD participants who had an impairment at the word level. Most of these participants had a word-level deficit that was related to the semantic lexicon or to the access to it. In this section we included participants with impaired semantic lexicon and individuals with intact semantic lexicon but with impaired access to it from input modalities (in these cases, production can be free of semantic errors but comprehension is impaired). Section 9.3 presents individuals with sentence level impairments, mainly syntactic impairments and their relations to other components. Section 9.4 presents the ASD participants who had no linguistic impairment, who had normal reading aloud, comprehension, naming, memory, and syntax. Finally, in Section 9.5 general results and conclusions are discussed.

9.2. Word level impairments (semantic lexicon)

Testing the semantic lexicon was one of the main questions of this study. Our results reveal that although some participants show an impaired semantic lexicon, this

impairment was never exclusive. A semantic deficit always coincided with at least one more impaired component as described in the following sections.

9.2.1 Semantic lexicon impairment

The semantic lexicon was found to be impaired in 11 of the 38 ASD participants and three more participants were found to have impaired access to semantics. The first step was to examine whether the deficit was on the conceptual level, namely, was it a deficit in the cognitive, a-modal component or whether it affected specifically the verbal component that stores the meaning of words, and which is used for comprehension and production – the semantic lexicon. To differentiate between a deficit in the conceptual system and a deficit in the semantic lexicon, we used tasks that required verbal input and output (various word comprehension tasks, the picture naming task, and a homograph reading task) testing the semantic lexicon, compared to tasks that required only picture comprehension with no verbal demands testing the conceptual system. The two tasks assessing the conceptual system involved understanding relations between two pictures. For some participants it seems that the task was unclear. If a participant had low scores on the two tasks testing the conceptual component (Odd one out words and Picture association (pyramids and plam trees) but his scores on the tasks explicitly testing semantics (word picture matching and picture naming) were high, it was concluded that his conceptual system is intact, because it is impossible to name pictures and perform a word-picture matching task when the conceptual system is impaired.

This analysis indicated that none of the 14 participants who showed a semantic deficit had an impaired conceptual system (once we take normal performance in at least one of the picture tasks or in picture naming to indicate unimpaired conceptual system).

Another important differentiation we made was between a deficit in the semantic lexicon itself and a deficit in accessing it from reading. Out of the five tasks testing the semantic lexicon (Odd one out words, Word association, Semantic homograph reading, Word picture matching and Picture naming) four involved reading. If a participant had low scores on the semantic tasks we examined whether the low scores were a result of a semantic deficit or a reading-related deficit. We examined the possibility of a deficit in the orthographic-visual analyzer, which would be expected to affect both words and nonwords, and a possibility of a deficit in accessing the semantic lexicon from the orthographic input lexicon. A deficit in the orthographic-visual analyzer was ruled out if the participant's reading aloud was normal. This was examined using the Tiltan task of word and nonword reading. If a participant had high scores, but still had low scores on the semantic tasks we could conclude that his orthographic-visual analyzer was intact but his semantic lexicon or the access to it was impaired. If a participant's score on the nonword reading task was low as well as scores on the semantic tasks, an in-depth error analysis was made of his reading on all tasks as well as on all the production tasks in order to differentiate between the two.

All 11 participants who were found to have an impairment in the semantic lexicon were also found to have an impairment at the sentence level (which will be discussed in Section 9.3). None of these participants were found to have an exclusive semantic deficit.

All had scores that were lower than their age matched norms on both NVIQ (RPM) and pragmatics (CCC), as seen in Table 13, which provides these participants' background information.

Table 13. Semantic lexicon impaired ASD participants: background measures

Participant	**Gender**	**Age**	**Diagnosis**	**RPM**	**CCC**
ID	M	9;3	Autism	68	118
SA	M	9;4	Autism	70	126
IC	M	9;9	Autism	78	128
SH	M	10;2	PDD-NOS	unable to complete task	97
RO	F	10;6	Autism	77	122
BA	M	10;6	LFA	unable to complete task	128
DA	M	10;9	HFA	75	120
YO	M	11;0	Autism	75	124
PE	M	11;4	HFA	70	122
OO	M	12;11	Autism	unable to complete task	121
OF	M	17;2	LFA	unable to complete task	108

Table 14 shows the individual scores of each participant in this group compared to the control group threshold. Shaded cells indicate a score lower than the impairment threshold for this task, i.e., performance that was significantly lower than that of the control group (and for the specific age group of the specific individual when control groups were divided by age). Empty cells indicate that the task was not accomplished.

Table 14. Semantic lexcion impairment: ASD individual scores (percent correct)

Component tested	Task	ID	SA	IC	SH	RO	BA	DA	YO	PE	OO	OF
Conceptual	Odd one out pictures	77	77	90		87	100	84	74	94	94	71
	Picture association	100	86	100	95	97	84	97	89	100	97	97
Semantic lexicon	Odd one out words (written)	71	25	50		79		46	71	63		
	Word association-Pyramids and palm trees(written)	92	73	78		89		68	59	62		
	Written word picture matching	90	90	75	85	95	75	85	70	90	100	60
	Picture naming	87	90	82	84	94	71	85	76	75	93	90
	Semantic homograph reading	65	75	85		77		77	88	100		
Orthographic lexicon	Word association-Ma kashur (written)	60	68	80		80		55	63	88		
Grapheme phoneme conversion, phonological output buffer	Tiltan Nonword reading	75	93	85		85		88	80	98		
Word reading route including phonological output lexicon	Tiltan single words	78	62	76		93		63	89	93		
Phonological input lexicon	Semantic-phonological word memory (auditory)			79				47		64		
lexical retrieval route (conceptual-semantic lexicon-phonological output lexicon)	picture naming phonological errors	1/14	1 / 8	1 /19	0 /14	1/6	4/24	1 / 12	0/24	1/25	0 / 6	0
	picture naming semantic errors	9/14	1/10	7/19	11/14	2/6	18/28	6/12	13/24	14/25	5/6	2/10
Syntax	**Repetition** Global score (auditory)	3	80	77		24		39	39	80		
	Structural errors	4	3	13		53		42	37	13		
	Lexical errors	4	16	9		18		26	24	12		
	Probability Judgment Global score (written)	66	81	92		80		79	86	75		
	Pronoun agreement judgment Global score (written)		63	50		63		83	77	50		
	Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)	57	66	86		80		82	84	70		
	Meguvana relative clause comprehension, comprehension questions Global score (auditory)	44	50	52		65		31	46	46		

All participants (except SA) performed on at least one of the tasks testing the a-modal nonverbal conceptual component at ceiling levels, indicating that the conceptual component was intact. Most had lower scores on the Odd one out picture task, indicating a specific problem with this task, or with the fact that it demanded a

more complex analysis of the stimuli (that constituted of four pictures versus only three in the picture association task).

The following sections will describe the individual profiles based on shared patterns.

9.2.3 Semantic impairment and a wide linguistic impairment

ID was the only participant that required a teacher or a teacher's assistant to sit with him during the testing sessions and help him cooperate. His attention span was extremely short and each session consisted of only one task. On most tasks he had trouble understanding the task demands and multiple training trails needed to be carried out until it was clear he had understood the task.

ID was able to complete the two tasks testing the Conceptual system, on the Odd one out task ID had a hard time understanding the task demands of pointing to an item that was different. Three training trails were carried out and he was asked to explain his choice when he chose a non target item. He would choose items that he thought were prettier or items that he personally liked better. Before every testing trail he was reminded of the instructions and that he needed to point to the item that was different. We note that this task had four pictures presented versus only three in the picture association (pyramids and palm trees) task. Based on his perfect performance on the Picture association (pyramids and palm trees) task as well as his performance on the word association task (pyramids and palm trees) and the word picture matching task, we concluded that his conceptual system is intact. ID's performance on these two tasks were in contradiction with his performance on the other two tasks testing the semantic lexicon, where he scored significantly lower than age controls. His score on the Picture naming task was impaired compared to his age group with all errors being semantic errors. Based on the scores of the semantic tasks and mainly the distinct

number of semantic errors on the naming task, we concluded that ID's semantic lexicon is impaired. Reading tasks were extremely hard for ID, on Word association – Ma kashur task his score was 60% correct (but his score could also be reflecting his semantic deficit) and on the Tiltan subtests his scores were all significantly lower than age controls, with errors of reading via the sublexical route, as well as migration of letters (in the same word and in between two different words), omissions, additions, morphological substitutions and deletions. When an error was made it was of an un lexical utterance (meaning he produced an utterance that was not a real word). Based on his scores and the many error types we concluded that his Orthographic lexicon, phonological input and output lexicons, and possibly his grapheme phoneme converter, were all impaired at some level.

ID was unable to complete all the syntactic tasks and on the ones he did complete it was unclear how much he understood the task demands. Probability judgment was one of the few tasks ID completed and his global score on this task was 66%. When looking at the individual sentence types it was possible to see by his score on simple and unprobable sentences that he did understand the task but that he seemed to have trouble with the more complex sentences. On the definition task ID was able to read most of the words (the ones that were not read correctly were read to him) and he seemed to understand all the words. His definitions included ungrammatical simple sentences.

(23) ID definition task examples

(1) Target: house

Production: house is to live

(2) Target: bed

Production: bed that sleep in

In conclusion, ID's pattern of impairment seems to show that the only component that is intact is the conceptual component. It should be noted that further tests are needed in order to better understand ID's linguistic impairment and test if some impairments could be affecting others, for example if his syntactic deficit is affecting his understanding of task demands or if his semantic deficit is affecting his syntactic understanding. His reading abilities would also need to be further tested as these seem to be impaired but not completely and finally it could also be possible that some variable that was not tested at all such as working memory or attention span is affecting his performance and has affected ID's language acquisition in the past. Another point that is important to consider is that ID had a very hard time understanding the task demands and therefore it could be that some scores on the more complex tasks are a result not only of the linguistic ability tested but also of ID's understanding (or lack of) of the task demands which are a result of his linguistic abilities.

DA was able to complete all 16 tasks, but had low scores on most of them. From his score on the Picture association (pyramids and palm trees) task we were able to conclude that his conceptual component is intact. DA's score on the Odd one out picture task was low and seemed to be a result of not understanding the task demands, a problem that seemed to occur on many tasks. His scores on all tasks testing the semantic component were lower than age matched controls and since his reading components seemed to be intact (because of his score on non word reading) we can assume that the low scores were not a result of impaired reading. On the picture naming task many semantic errors were seen and on the word memory task DA did better on phonological distracters than on semantic ones. On the comprehension of mental verbs, DA seemed to consistently choose the more concrete distracter and in

the reading and paraphrasing task tended to add information that had not appeared in the original sentence. DA's scores on the syntactic tasks were low as well and seemed to show that he did better on syntactic tasks testing comprehension than production. His definitions, although he read and understood all the words were inconsistent, some single word definition, some ungrammatical sentences and some sentences with relative clauses. Summarizing, it seems that DA has an impairment in his semantic lexicon and syntax, as well as a more general deficit that lead to trouble in understanding task demands.

9.2.4 Semantic impairment, syntactic impairment and dyslexia

SA showed a very inconsistent pattern of performance. On the two tasks testing the conceptual component SA scored significantly below his age equivalent TD peers (see table 14). On the tasks testing the semantic lexicon component his scores were low as well with the exception of the Word picture matching task (90%) and the picture naming task (90%). Based on these two tasks (word picture matching and picture naming) we were able to conclude that SA's conceptual component as well as his semantic component is intact. On the picture naming task no phonological errors were seen which strengthened the hypothesis that his phonological input lexicon is intact. SA's score on the Homophone comprehension task was very low (63%) and since his reading on the Tiltan nonwords subtest was 93% correct we were able to conclude that his orthographic lexicon as well as his grapheme phoneme converter were intact and there seems to be a deficit in semantics. All the tasks on which SA had low scores on included reading with meaning (his nonword reading was good) and relations between words pointing to a deficit inside the sematic component involving word relations (his single word comprehension and production seems to be intact by his score on picture naming). His reading on the Tiltan single

words and pairs of word subtest indicated that SA was reading via the sub-lexical route consistently and he had many errors that were indicative of Surface dyslexia and Attention dyslexia (he seems to have both types). SA's results on the syntactic tasks seem to be a result of a syntactic impairment as well as a result of his dyslexia's. On the repetition task he had low scores on all sentence structures except the simple sentences but the fact that he had mainly lexical errors strengths the hypothesis of a semantic deficit as did his performance on the sentence comprehension task with similar semantic and phonological NP's. On the semantic syntactic reactivation sentence comprehension task no differences were seen on sentences with a shorter versus longer word gap, but SA's performance on subject relatives was much better than on object relatives (72%, 58% respectively). On the probability task SA achieved 90% correct on sentences with verb movement, embedded sentences and simple sentences. On the simple and improbable sentences his score was 80% correct and on the WH sentences 75% correct. And finally on the grammaticality judgment task SA had low scores on both parts (67%, 60%).

IC on the other hand showed a very clear pattern of impairment. On all the tasks testing the conceptual system his scores were intact, but on all tasks testing the semantic lexicon his scores were low. Error analysis of the semantic tasks revealed that IC was making many semantic errors, on the Odd one out words, Word association (pyramids and palm trees) and Word picture matching task he seemed to have trouble diffrentitating between close category items. On the picture naming task IC achieved a low score (82%) with many semantic errors showing a clear semantic deficit. On all the reading tasks IC had many errors of migration and ommisions of letters indictaing a Letter Position Dyslexia (and possibly also Surface dyslexia but not enough tasks were administerd to know). Finally on all the tasks testing syntax IC

showed a clear pattern of impairment in WH movement. Some of the scores on his syntactic tasks were also affected by his reading abilities resulting in reading errors that affected his comprehenshion.

SH, was able to complete only 3 out of the 16 tasks. SH was able to complete only one out of the two tasks testing the conceptual component, the Picture association (pyramids and palm trees) task on which he scored at an age equivalent level (95% correct). Based on his performance on this task (as well as the other two tasks in which other errors were evident) we concluded that his conceptual component is intact. The other two tasks that SH completed were the Word-picture matching task (in which the words were read to him; 85% correct) and the Picture naming task (84%) in which most of his errors were either semantic or associative. Based on these two tasks we concluded that SH has impairment in the semantic lexicon, and since no phonological errors were seen on the picture naming task his phonological input and out put lexicons are most likely intact.

Strengthening the hypothesis that his phonological lexicons are intact is the part of the Tiltan reading task that SH completed. He read 82 words (out of 136) on the single word reading task and then refused to cooperate and read more words. Out of the 82 words he did read, he read 83% of them correctly with most errors being errors that are indicative of a Letter Position Dyslexia (LPD). Since he didn't complete the non word reading sub task or the word pairs sub task we interpret his results with caution, but it seems that his Orthographic lexicon is impaired (LPD) while his phonological lexicons and grapheme phoneme converter are intact. SH was not cooperative on any of the syntactic tasks (including the definition task) and so we have no way of knowing what his syntactic abilities are, although from observations in the class room, it seemed that the teachers corrected his grammar when he asked

for things quite often (for example when asking for something would say: 'ani, ze, rotze', 'me, that, have' – which is an ungrammatical sentence in Hebrew).

OO was able to complete five out of the sixteen tasks in this study. OO was found to have an intact conceptual component (see Table 14 for scores). From looking at his scores on the tasks testing semantics it seems that his semantic lexicon is intact, but error analysis of his productions in the definition task reveals that OO has trouble retrieving the correct semantic information (ex. 25). His definitions were incomplete relative clauses that were at times wiered, pointing to a pragmatic deficit. The phonological input and output lexicons seem to be intact as no phonological errors were seen. None of the reading tasks were administered and so we don't know if these components are intact or not, but from his attempts at reading the words in the definition task it seems that he might have LPD as well with many of the letters migrating inside the same word.

(24) OO definition example

Target: ירקות

Yerakot

vegtables

Production: ירקות זה למשל תפוז, לא ירקות זה לא, זה כל מיני ירקות כאלה לא טעימים...אוכל

Yerakot ze lemashal tapuz, lo, yerakot ze lo, ze kol mini yerakot ka-ele lo te-imim…oxel.

Vegetables is for example (an) orange, no vegetables is not, it's all kinds of vegetables (that) aren't tasty...food.

9.2.5 Semantic impairment and syntactic impairment

RO and PE showed TD-equivalent performance on all tasks testing the orthographic lexicon, grapheme-to-phoneme conversion and the phonological output lexicon, indicating these components were intact. Both showed impaired performance on all tasks testing syntax and semantics.

BA and OF were two participants with LFA. They were unable (or refused) to complete most of the tasks in this study. It was decided to include them in the results analysis because from the tasks they were able to complete it was possible to get at least a partial picture of their linguistic difficulties. Based on the fact that OF had no phonological errors on any task, and BA had only a small number of phonological errors on the Picture naming task, it was concluded that their phonological output lexicon was intact BA and OF also completed the definition task (of which the analysis was mainly qualitative and therefore scores were not incorporated into the table).From their definitions we were able to conclude that they understood all the words in the task, but that both had a syntactic impairment as manifested in their definitions, which included sentences with ungrammatical relative clauses, single words and definitions that were linked to a more personal association than to the conventional definition of the word (ex. 26), showing a syntactic deficit as well as a pragmatic one.

(25) Definition examples BA

(26.1) personal association

Target word for definition: שמח

Sameach

Happy

Production: שמחים זה שמתרגשים, או חודש אפריל

Smechim ze she-mitragshim, ou xodesh april

'happy (times) that (get) excited, or the month of April'

(26.2) ungrammatical sentence

Target word for definition: מזלג

Mazleg

Fork

Production: מזלגות, תופסים אותם אוכל ואוכלים כמו בני אדם

Mazlegot, tofsim otam ochel ve-ochlim kemo beni adam

'forks, catch them food and eat like human beings'

(26.3) single word definition

Target word for definition: טלפון

Telephone

Telephone

Production: מתקשרים

'calling'

Summarizing, 12 children with ASD were found to have an impaired semantic lexicon. All were also found to be impaired in other linguistic components with some showing a vast deficit in linguistic abilities. The majority of this group had impaired scores on NVIQ and pragmatics, again pointing to an impaired semantic component as part of a vast cognitive deficit.

9.2.6 Impaired access to semantics as well as syntactic deficit

The following three participants were found to have an intact semantic component, but impaired access to the semantic component. These participants showed inconsistent scores on semantic tasks and in fact if they had only been tested

on Picture naming would have been found as unimpaired. Table 15 shows their background measures and Table 16 individual scores.

Table 15. Access to semantics and syntax impaired: background measures

Participant	Gender	Age	Diagnosis	RPM	CCC
TE	M	8;5	Classic Autism	65	140
SZ	M	8;11	Classic Autism	84	131
YM	M	11;7	Classic Autism	41	101

Table 16. Access to semantics and syntax imapired: individual scores

Component tested	Task	TE	SZ	YM
Conceptual	Odd one out pictures	84	87	74
	Picture association(pyramids and palm trees)	97	92	100
Semantic lexicon	Odd one out words	75	75	54
	Word association(pyramids and palm trees)	89	84	84
	Word picture matching	95	85	90
	Picture naming	95	87	96
	Semantic homograph reading	85	73	73
Orthographic lexicon	Word association – Ma kashur	85	63	83
Grapheme phoneme conversion, phonological output buffer	Tiltan Nonword reading	83	98	95
Phonological input lexicon	Semantic-phonological word memory		61	
Word reading route including phonological output lexicon	Tiltan single words	96	75	88
* phonological errors out of overall errors for participant	picture naming (phonological errors)	0	0	0
Syntax	**Repetition** Global score	74	90	63
	Wh movement	72	84	48
	verb movement	50	70	50
	A movement	93	100	87
	Embedded sentences	80	100	70
	Simple sentence	70	100	90
	Probability Judgment Global score	71	82	
	Wh movement	55	68	
	verb movement	80	90	
	Embedded sentences	80	100	
	Simple sentence	85	95	
	Simple improbable	100	100	

	Pronoun agreement judgment Global score	47	43	
	score part 1	53	47	
	score part 2	40	40	
	Mekayim relative clause comprehension sentence-picture matching Global score	57	82	57
	2 word distance	74	83	52
	9 word distance	35	74	57
	Subject relative	68	96	64
	Object relative	42	63	47
	Meguvana relative clause comprehension, comprehension questions Global score	65	71	54
	Subject relative	54	79	63
	Object relative	54	63	46
	Semantic distracters	63	63	63
	Phonological distracters	50	75	31

TE was the youngest participant in this study and had low scores compared to norms on both the RPM and CCC. His scores on the conceptual and semantic tasks were inconsistent but due to his high scores on the Picture association (pyramids and palm trees) task, the word picture matching task and the picture naming task we concluded that his conceptual component as well as his semantic component is intact. TE's score on the Odd one out words, Word association (pyramids and palm trees), Semantic homograph reading task and Word association (Ma Kashur) task were lower than controls (but over 70% showing he had understood the task), and since his reading scores on the Tiltan tests were good we concluded that the problem in these tasks is semantic related. Since TE's score on the picture naming was age matched we concluded that the impairment wasn’t in the semantic lexicon itself but rather in accessing it. On the picture naming task, when TE made a mistake, twice he produced a gesture instead of the target word, pointing to the fact that he is able to access the word at some level but then has trouble producing it. On all tasks testing syntax TE had low scores, in several tasks he had scores on simple sentences that were age

matched hinting that he may have some parts of syntactic comprehenshion intact, but there were tasks were his scores were low on all sentence types which could either be a result of a broad syntactic impairment or of the semantic deficit affecting syntax as well. On the reading and paraphrasing task TE's reading scores were much better on the simple sentences compared to sentences with relative clauses, strengthening the hypothesis of a syntactic deficit. On the definition task he seemed to understand all the words but his definitions included either single words (verb plural) which are typical of younger children or ungrammatical utterances. In conclusion it seems that TE has an impairment in accessing his semantic lexicon as well as syntactic deficit. We can't tell the exact nature of the syntactic deficit as it seems that the semantic access deficit also had an effect on his performance on these tasks.

SZ showed a very inconsistent pattern of performance on all tasks. We concluded that his conceptual component is intact based on his age equivalent scores both on the picture association task and the picture naming task. On the second conceptual task, the Odd one out in picture task, SZ scored just below the threshold for impaired performance; this was also the case for his score on word picture matching. In both cases his low scores seemed to be a lack of world knowledge. On the picture naming task, although his score was lower than age controls, 4/13 errors were definition errors showing that he was able to access word meaning. Moreover, on the definition task, all his definitions showed that he was able to acess semantic knowledge of the word. When we looked at the syntactic tasks, a clear picture of a WH-movement impairment appeared, with significantly low scores on sentences with WH-movement and age equivalent scores on all other sentence types. When analysisng SZ's errors on the repetition task, we found that no lexical errors were made (only structural), hence streghthening the hypothesis that his semantic lexicon

was intact but accessing it was problematic. This hypothesis was further supported by SZ's score on the mental verb task on which he scored at an age equivalent level (95%), as well as by the fact that he achieved an age equivalent score on homograph reading in the Reading and paraphrasing homograph task (90%). Both scores would not have been possible if his semantic lexicon were impaired. Next we looked at SZ's scores on the reading tasks and found that a disconnection between the orthographic lexicon and the semantic lexcon was causing SZ's low scores on the semantic tasks. SZ's score on the Non-word reading task was 98% correct – showing there was no impairment in any of the components of the sub-lexical route to reading. When SZ was asked to read real words and hence use his lexical route to reading, his scores dropped (single word reading 75%, word pairs reading 80%) and when he produced an error in these tasks it was of an unlexical utterance pointing to a disconnection with the semantic lexicon. In conclusion, SZ was found to have a disconnection between his orthographic lexicon and the semantic lexicon, he might also have a disconnection between his phonological lexicon and the semantic lexicon, but the tasks used in this study weren't sensitive enough to show this clearly.

YM was the third participant found to have an impairment in accessing the semantic lexicon, and he showed a pattern of impairment similar to that found for TE and SZ, although his syntactic deficit was more obvious, with very low scores on all syntactic tasks. Out of the two tasks testing the conceptual component, YM scored at an age equivalent level only on one (Picture association -pyramids and palm trees: 100%); on the Odd one out picture task YM seemed to not understand the task demands. On the four tasks testing the semantic component he scored at an age equivalent level only on one (Odd one out words: 54%, Word association (Pyramids and plam trees): 84%, Homograph reading: 73%, Word picture matching: 90%).

Although YM's scores were inconsistent, from the picture association score, the word picture matching score and the score on the picture naming task (96%) we were able to conclude that his conceptual and semantic components are intact. Although his reading was slightly lower than his age equivalent peers (Word association – Ma kashur 83%, Tiltan single words 88%), we were able to conclude that his orthographic lexicon, grapheme phoneme conversion and phonological input lexicon were intact based on his score in reading non-words (95%). Based on this score we were able to also conclude that the low scores on the tasks testing the semantic component were not a result of a reading deficit but of trouble accessing semantics through reading, as his scores on tasks testing the semantic component with no reading were intact.

In summary, all three participants showed intact semantic lexicon abilities but a deficit in accessing the semantic lexicon, as was seen in more complex tasks than the picture naming task. SZ had a clear syntactic WH-movement impairment as well, but for TE and YM we cannot know the exact nature of the syntactic impairment due to the overlap with semantic access, that is needed in order to perform correctly on these tasks.

9.2.7 Semantic impairment: conclusions

Out of the 38 participants with ASD, 11 were found to have impairment in the semantic lexicon and 3 were found to have impairment in accessing the semantic lexicon. Of these, none had an exclusive semantic deficit. Some participants, although having impaired acess to the semantic lexicon were able to achieve relatively high scores on the picture naming task, questioning this task's ability to assess linguistic competence. An impairment in lexical semantics inevitably affects the comprehension also at the sentence level, and in some of our ASD also co-occurred with a syntactic

impairment (as will be discussed in the next section). Some of the participants with a semantic deficit also had different types of dyslexia.

9.3 Sentence level impairment – impaired syntax

One of this study's research questions was whether a semantic impairment would affect other linguistic abilities and whether impairment in the semantic lexicon would cause an impairment in other linguistic areas. Out of the 38 participants with ASD, 29 were found to have impairments at the sentence level. The following sections will describe the different syntactic impairments found and their relationship to lexical semantics.

9.3.1 Syntactic movement impairment

Twenty participants exhibited a syntactic profile that is common in other language pathologies that involve a selective syntactic impairment, with impaired performance on complex syntactic structures (mainly WH-movement and verb movement) alongside age-matched performance on simple sentences.

9.3.1.1 Exclusive Syntactic movement impairment

Of the 20 participants who showed syntactic movement impairment, 10 had a selective syntactic deficit, with no other linguistic impairment (including no impairment detected in the semantic lexicon). Table 17 shows background information for these participants, who were of different ages, and who had very different NVIQ and pragmatic scores.

Table 17. Participants with an exclusive syntactic impairment: background measures

Participant	**Gender**	**Age**	**Diagnosis**	**RPM**	**CCC**
MA	M	9;6	Autism	98	133
SC	M	10;3	HFA	98	122
YR	F	10;9	Autism	58	105
AR	M	11;1	HFA	73	122
AD	F	11;2	HFA	106	132
GA	M	12;7	HFA	57	131
IT	M	12;11	Autism	79	138
AT	M	13;5	Autism	99	138
OM	M	13;2	HFA	91	122
NG	M	17;9	Autism	95	147

Table 18 presents the participants' individual scores on the syntactic tasks. All of them scored at an age-matched level on the two tasks testing the conceptual component. All of them had TD matched scores on the word-picture matching task and on the picture naming task, indicating that their semantic lexicon and phonological lexicons were also unimpaired. Some participants had scores lower than controls on the Odd one out word task and the Word association task, in all cases a behavioral pattern was observed indicating that the low scores were a result of lack of cooperation or fatigue.

On the semantic homograph reading task, two participants had scores that were lower than controls. In both cases it seems that this could have resulted from lack of world knowledge and from not being acquainted with the second meaning of the homograph.

On the nonword reading task all participants scored at their age matched level indicating that their orthographic input buffergrapheme-to-phoneme converter and the phonological output buffer were intact. On the semantic/phonological word memory task all but two of the participants performed at an age matched level. The two participants who had lower scores seemed to have trouble understanding the task demands.

Turning to the syntactic tasks; on the sentence repetition task some participants (MA, SC, AR, AD, IT, OM, NG) showed a very clear pattern of impairment, with lower scores on complex sentence types and intact performance on simple sentences while two other participants were found to be TD matched in their performance (YR, GA).

On the Pronoun agreement judgment task, all the participants who completed this task had good scores on the first part of the task, which included sentences with verb movement in which the antecedent also appeared in the canonical argument position, and low scores on the second part, where both sentences had the same sentence structure, but the verb and the verb complements were synonyms and not matched in gender in the ungrammatical condition.

On the Sentence picture matching task most participants had age equivalent scores on sentences with subject relatives and low scores on object relatives. MI had lower scores than controls on both sentence types but her score on subject relatives was still better than their score on object relatives. Four participants (GA, IT, NG) did well on all sentence types and it seems that the fact that this task had pictures aided their performance.

The Sentence comprehension with similar semantic/phonological NP's task seemed to be hard for most participants, all but one (OM) showed better performance (not always age matched) on subject compared to object relatives.

On the plausibility judgment task that had the same sentence types as the repetition task, all participants scored at an age matched level. It seems that this task was less sensitive to syntactic impairments and that the improbable component of the task helped the participants overcome the syntactic complexity.

Finally, all participants in this group, except for AD, produced sentences displaying impaired syntax in the definition task.

Table 18. Selective syntax impairment: individual scores in the various structures in the syntactic tasks

Task	MA	SC	YR	AR	AD	GA	IT	AT	OM	NG
Repetition Global score	84	61	93	76	64	87	84	99	91	81
Wh movement	80	48	88	92	44	84	84	96	84	56
verb movement	40	20	100	10	50	70	80	100	90	100
A movement	100	87	93	87	87	93	87	100	93	100
Embedded sentences	100	90	100	80	60	100	90	100	100	100
Simple sentence	100	80	100	90	100	100	90	100	100	90
Pronoun agreement judgment Global score	67	87	60	87	63	83	80	90	90	90
score part 1	86	93	80	100	86	86	93	93	93	80
score part 2	46	80	40	73	40	80	66	86	86	100
Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)	75	73	91	89	73	98	95	86	91	98
2 word distance	74	70	91	87	74	96	91	91	87	100
9 word distance	70	70	83	83	65	91	91	74	87	87
Subject Relative	96	92	100	100	100	100	100	96	96	96
object relative	47	47	79	74	37	95	89	74	84	100
Meguvana relative clause comprehension, comprehension questions Global score (auditory)	54	83	75	69	56	75	63	69	88	52
Subject relative	79	88	92	79	75	92	71	79	88	71
Object relative	29	79	58	58	38	58	54	58	88	33
Semantic distracters	56	94	88	63	44	69	75	69	88	44
Phonological distracters	56	69	69	56	63	81	63	69	88	56

Probability Judgment Global score	94	94	96	94	89	93	98	94	98	100
Wh movement	88	93	95	88	83	90	95	90	95	100
verb movement	100	100	100	100	90	100	100	100	100	100
Embedded sentences	100	90	100	100	90	90	100	100	100	100
Simple sentence	100	95	95	100	100	100	100	95	100	100
Simple improbable	100	100	100	100	100	80	100	100	100	100
Relatives produced in the definition task (written word) definition included SR / OR / no R / single words	none	Some OR	Some OR	Some OR	Some OR	Some OR	none	none	Some OR	Some OR

AD showed a syntactic pattern similar to the rest of the participants in this group, but her definitions were different. She used relative clauses as expected for her age group, but did not produce two NP's as expected in the relative clause hence making her sentences sound a bit weird (for example, to define the word ‘swing’ she produced the sentence: ‘something you swing at’ which is a relative clause but not the relative clause you would expect in terms of the NP and verb complementizers). She seemed to have trouble with syntactic structures that involve intervention - movement of a lexically restricted objects across lexically restricted subjects; she also showed a mild deficit in morphology, which was evident in her oral reading as well as in her sentence repetition errors.

Summarizing, 10 children with ASD were found to have an exclusive syntactic impairment while all other components were found to be intact. Most of these children exhibited a common profile of impairment typically found in other language related pathologies, such as syntactic SLI, wherein there is better comprehension and production of structures without Wh-movement, or structures in which there is no Wh-movement of the object across the subject. The inter-participant performance indicates that their impairments differed in degree of severity and the fact that some participants showed intact performance

on some of these tasks stresses the importance of having more than one task and one modality. The Sentence comprehension task "Meguvana" and the Definition task seemed to be the most sensitive to subtle syntactic impairment as these were the tasks which pinpointed impairment even in the participants who achieved TD scores on the other tasks.

9.3.1.2 Syntactic movement impairment in addition to other impairments

Eight participants were found to have a syntactic movement deficit as well as other impairments. Most of them had lower than normal scores for both Raven's PM and the CCC. Table 19 shows background information about these participants. Participants who were found to have a semantic related impairment have been described in the previous section and here only their syntactic scores are presented (SZ, SA,IC, DA, PE).

Table 19. Syntactic movement impairment and other impairments: background measures

Participant	**Gender**	**Age**	**Diagnosis**	**Raven PM**	**CCC**	**Impaired location**
SZ	M	8;11	Classic Autism	84	131	syntax + acess to semantics
SA	M	9;4	Classic Autism	70	126	Syntax + semantics + dyslexia
IC	M	9;9	Classic Autism	78	128	Syntax + semantics + dyslexia
DA	M	10;9	HFA	75	120	Wide cognitive deficit
PE	M	11;4	HFA	70	122	syntax + semantics
YU	M	11;2	Classic Autism	68	111	Syntax+ orthographic lexicon + phonological input lexicon
TZ	M	11;9	Classic Autism	63	120	Syntax + phonological working memory
MO	M	13;3	Classic Autism	86	135	Syntax + phonological output buffer + dyslexia

Table 20 presents the participants' individual scores on syntactic tasks. On the repetition task five participants (SZ, SA, DA, YU, TZ) showed a clear WH-movement impairment with low scores on sentences with WH-movement and intact scores on simple sentences. The other three participants seemed to show impaired performance also on the simple sentences and it seems that their other impairments were affecting their scores. MO had a phonological output buffer impairment and since this task also included a memory component MO had low scores on all sentence types with a slight difference between structural and lexical errors.

Table 20. Synatactic movement impairment and other impairments: individual scores on syntactic tasks

Task	SZ	SA	IC	DA	PE	YU	TZ	MO
Repetition Global score	90	80	77	39	80	93	84	49
Wh movement	84	76	80	16	72	88	72	44
verb movement	70	80	50	30	60	100	90	20
A movement	100	80	93	53	100	93	93	60
Embedded sentences	100	80	70	50	90	90	100	90
Simple sentence	100	100	80	90	80	90	90	60
Probability Judgment Global score	82	81	92	79	75	98		73
Wh movement	68	75	85	63	65	100		50
verb movement	90	90	90	100	80	100		100
Embedded sentences	100	90	100	90	100	80		80
Simple sentence	95	95	100	90	85	100		95
Simple improbable	100	80	100	100	60	100		100
Pronoun agreement judgment Global score	43	63	50	83	50	93	63	67
score part 1	46	66	46	80	60	100	80	73
score part 2	40	60	53	86	40	86	46	60
Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)	82	66	86	82	70	77	89	64
2 word distance	83	65	91	87	57	91	83	65
9 word distance	74	61	74	70	78	57	87	57
Subject Relative	96	72	100	80	92	84	88	88
object relative	63	58	68	84	42	68	89	32
Meguvana relative clause comprehension, comprehension questions Global score (auditory)	71	50	52	31	46	75	65	46
Subject relative	79	88	75	29	50	75	58	67
Object relative	63	79	29	33	42	75	71	25
Semantic distracters	63	94	56	44	63	75	75	63

Phonological distracters	75	69	38	19	31	69	63	50
Definition task (written word) definition included SR / OR / no R / single words	Some OR	Some OR	Some OR	Some OR	Some OR	Some OR	Only SR	Some SR

The probability judgment task was built using the same sentence structures as the repetition task, but this task was presented visually so the participants could read, and the implausible sentences were funny, which seemed to improve performance on most sentence structures. The scores for most of the participants on sentences with WH movement were impaired, while other sentence types were age matched. YU was able to achieve a high score on the WH sentences but had a low score on embedded sentences. PE and SA had low scores also on simple sentences (PE- simple sentences: 80; SA- simple sentences: 85; simple and unprobable: 65). Both participants were found to have an impaired semantic lexicon and since they were able to achieve high scores on other sentence types their low scores were attributed to their semantic deficit.

The relative clause comprehension sentence-picture matching task (Mekayim) involved listening to a sentence and pointing to the corresponding picture. This task tested both memory functions (with the change in distance between the antecedent and the trace of two words versus nine words) as well as sentences with subject relatives versus object relatives. The global score of all participants except TZ was lower than controls. TZ's syntactic impairment seems different than the rest of the group as will be described at the end of this section. The word distance seemed to influence the results of three participants (IC, DA, YU) who had intact scores on sentences with a two-word distance compared to impaired scores on sentences with a nine-word distance. The remaining four participants (SZ, SA, PE, MO) had impaired scores on both sentence types. Next we looked at the syntactic structure of the sentence, all the participants, except TZ, were found to have impaired performance on sentences with object relatives. SZ, IC, PE and MO had intact scores on sentences with subject relatives. SA, DA and YU had impaired scores on the sentences with subject relatives

(as well as on the object relatives), but these were in all cases still higher than the scores on the sentences with object relatives. All the participants (except SA) had low scores on the Meguvan - relative clause comprehension, comprehension questions task which was an auditory comprehension task with no written or pictorial aides. SA had intact scores on the sentences with subject relatives and impaired scores on his object relatives which is expected by his impaired syntax profile. Surprisingly he had intact scores on the semantic distracters (although he was found to have a semantic impairment) and impaired scores on the phonological distracters. It seems that SA may have a phonological deficit that our tasks were not sensitive enough to track.

TZ's error patterns on the syntactic tasks and especially the definition task suggested that his syntactic impairment was different than the other participants in this group. On the one hand he produced many sentences with relative clauses but on the other he produced ungrammatical sentences. In-depth analysis of his definitions revealed that he seems to omit the PPs that include resumptives and have incorrect reference in the relative clauses and may suggest trouble with refererring in a sentence, possibly due to a pragmatic deficit. His scores and error patterns on the similar semantic/phonological NP sentence comprehension task, sentence picture matching task and the repetition task also show that TZ seems to have deficit in phonological working memory.

Summarizing, eight participants were found to have a WH syntactic deficit as well as other impairments. Based on the participants' scores and error analysis we were able to see that some of the scores on the syntactic tasks were not only a result of the syntactic impairment and that other linguistic deficits do interact and affect syntactic comprehension and production.

9.3.2 Syntactic movement impairment as a result of auditory access to syntax

Two participants (SB and SK) exhibited a pattern of impairment similar to the one found in the previous group, but in-depth error analysis revealed that the source for impairment was different. The previously described groups had a syntactic deficit in the syntactic component while the following two participants had an impairment in accessing the syntactic component auditorily. SB was also found, in addition, to have a phonological working memory deficit. Table 21 presents the participants background measures.

Table 21. Syntactic movement impairment as a result of auditory access to syntax: background measures

Participant	**Gender**	**Age**	**Diagnosis**	**RPM**	**CCC**
SB	M	10;4	PDD-NOS	84	122
SK	M	15;11	HFA	111	148

Table 22. Syntactic movement impairment as a result of auditory access to syntax: individual scores on syntactic tasks

Task	SB	SK
Repetition Global score	90	53
Wh movement	84	52
verb movement	80	10
A movement	93	87
Embedded sentences	100	100
Simple sentence	100	50
Probability Judgment Global score	100	98
Wh movement	100	98
verb movement	100	100
Embedded sentences	100	90

Simple sentence	100	100
Simple improbable	100	100
Pronoun agreement judgment Global score	100	93
score part 1	100	100
score part 2	100	86
Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)	100	82
2-word distance	100	91
9-word distance	100	65
Subject Relative	100	84
object relative	100	79
Meguvana relative clause comprehension, comprehension questions Global score (auditory)	81	50
Subject relative	96	63
Object relative	67	38
Semantic distracters	81	63
Phonological distracters	88	56
Definition task (written word) definition included SR / OR / no R / single words	Some OR	Some OR

As seen in Table 22 SB and SK had ceiling level scores on most tasks, but each had several scores that were significantly lower than controls on specific subtasks.

SB had norm matched scores on his NVIQ and pragmatic measures. He had almost perfect performance on all tasks testing his conceptual component and semantic lexicon as well as on all the reading tasks indicating that his orthographic lexicon, phonological lexicon and grapheme phoneme-converter were intact.

On the Definition task, SB read all the words correctly and his definitions were good pragmatically as well as syntactically, indicating that his syntax production abilities were good. The rest of SB's scores on the syntactic tasks seemed to be inconsistent with some at ceiling while others were very low (see Table 22). Taking into account the low score that SB achieved on the semantic/ phonological word memory task and his varying performance on the syntactic tasks we concluded that SB had a deficit in auditory access to syntax as well as a phonological input working memory deficit.

SK seemed to exhibit a similar pattern with high scores on all tasks except on syntactic tasks and even then, all scores were over 80% correct (see Table 22) but there were also syntactic tasks in which he scored at ceiling levels (sentence picture matching, probability judgment and grammaticality judgment). Error analysis revealed that SK's syntax is intact (as well as all other components tested), but that SK seems to have trouble when he needs to comprehend sentences with syntactic movement, with exclusively oral input. His low scores were only on tasks with no visual aid (pictures or reading), and on these, his low scores were only on sentences with syntactic movement and so it was concluded that SK had an impairment in auditory access to syntax.

Conclusions: syntactic movement impairment

Twenty participants with ASD were found to have a syntactic impairment. Of these, ten were found to have an exclusive syntactic impairment, with all other components (including semantics) intact. Eight were found to have a syntactic deficit as well as at least one other component impaired (four of them had a semantic impairment). For some of these participants, it was possible to see that their different impairments were affecting their syntactic performance, but not for all of them. Two more participants were found to have an impairment in auditory access to syntax and their syntactic performance resembled the two other groups.

9.4 Overall syntactic impairment

The following group of nine participants were found to have a syntactic impairment that seemed to affect all sentence types. Their overall syntactic comprehension and production abilities were low and all were found to have other impaired components (mainly semantic lexicon or access to it). Out of these nine participants, only five were able to complete most of the study tasks. We begin with these five particcipants, and then move on to the four participants for whom we were able to identify a wide syntactic deficit, despite the fact that they only completed a small number of tasks.

9.4.1 Wide syntactic impairment

Five participants were found to have low syntactic scores on most sentence types on most tasks testing syntax. All performed below norms for NVIQ and pragmatics, indicating that they had a wide cognitive deficit. Table 23 shows these participants' background measures.

Table 23. Wide syntactic impairment: background measures

Participant	**Gender**	**Age**	**Diagnosis**	**RPM**	**CCC**	**Additional impaired location**
TE	M	8;5	Autism	65	140	Access to semantics
ID	M	9;3	Autism	68	118	All other components except conceptual
RO	F	10;6	Autism	77	122	Semantic lexicon
YO	M	11;0	Autism	75	124	Semantic lexicon
YM	M	11;7	Autism	41	101	Access to semantics

Table 24. Wide syntactic impairment: individual scores on syntactic tasks

Component tested	Task	TE	ID	RO	YO	YM
Syntax	**Repetition** Global score	74	3	24	39	63
	Wh-movement	72	0	16	32	48
	verb movement	50	0	10	10	50
	A-movement	93	0	40	53	87
	Embedded sentences	80	10	70	40	70
	Simple sentence	70	10	30	70	90
	Probability Judgment Global score	71	66	80	86	
	Wh-movement	55	70	80	80	
	verb movement	80	40	100	90	
	Embedded sentences	80	60	60	90	
	Simple sentence	85	65	75	90	
	Simple improbable	100	100	100	100	
	Pronoun agreement judgment Global score	47		63	77	
	score part 1	53		93	100	
	score part 2	40		33	53	
	Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)	57	57	80	84	57
	2-word distance	74	70	70	91	52
	9-word distance	35	39	83	70	57
	Subject Relative	68	56	100	84	64
	object relative	42	58	53	84	47
	Meguvana relative clause comprehension, comprehension questions	65	44	65	46	54

	Global score (auditory)					
	Subject relative	54	46	83	63	63
	Object relative	54	42	46	29	46
	Semantic distracters	63	31	69	56	63
	Phonological distracters	50	56	63	31	31
	Definition task (written word) definition included SR / OR / no R / single words	Single words	No R	Some SR	Single words	No R

On the repetition task, ID, RO, and YO had impaired scores on all sentence types. All three participants were also found to have an impaired semantic lexicon and for ID and YO there wasn't a significant difference between lexical errors and structural errors, indicating that the semantic impairment was also affecting performance. RO had more structural errors (53) compared to lexical errors (18), but the high rates of lexical errors indicate that the semantic impairment was affecting his performance as well. TE and YM had low scores on sentences with WH movement, verb movement and embedded sentences but had intact scores on sentences with A-movement (TE: 93; YM: 87). YM also had an intact score on simple sentences (90). Both participants were found to have an impairment in accessing the semantic lexicon and their deficit seemed less profound than the other three participants. TE had more lexical errors than structural errors (17, 10 respectively), while YM had more structural than lexical errors (24, 20 respectively) but the difference between them was insignificant. The high rates of lexical errors again points to the impaired access to semantics as being part of the reason for impaired performance. On the probability judgment task that used the same sentence structures as the repetition task, most participants performed better than the repetition task. It seems that the difference was due to the task demands, wherin the repetition task involved auditory comprehension and memory, the probability task was presented in written form and had funny sentences. YO had impaired scores only on sentences with WH-

movement, RO had impaired scores on sentences with WH-movement, embedded sentences and simple sentences but had intact scores on sentences with verb movement and simple and improbable sentences. TE and ID had impaired scores on all sentence types except the simple and improbable sentences, and finally YM refused to cooperate on this task. The fact that all participants had intact scores on the simple and improbable sentences suggests that their semantic and semantic related deficits are affecting performance and understanding even in simple sentences. The violation of probability in the simple and improbable sentences was the largest ("this is the strawberry who loved to dance") and it seems that even participants that had a hard time judging probability (based on their semantic impairments) were able to overcome and judge these sentences correctly. The pronoun agreement task was also presented with written aide. On this task ID and YM saw the number of sentences and refused to cooperate. RO and YO on the other hand were able to achieve intact scores on part one of the task but impaired scores on part two (as was the typical pattern of impairment in the group of children with syntactic movement deficits). TE, had a higher score on part one than part two, but still both scores were impaired pointing to the fact that for TE, the written aide of this task did not influence performance. The Mekayim - relative clause comprehension sentence-picture matching task was a task in which the participants were not required to produce an answer. They were asked to listen to a sentence and point to one of two pictures depicting opposite scenarios. Sentences included sentences with subject relatives and object relatives as well as different distances between the antecedent and the trace (2 words compared to 9 words). TD, ID, YM were found to have impaired scores on all sentence types. RO was found as having impaired scores on sentences with object relatives (53) but a perfect score (100) on subject relative sentences, showing that the picture aide in this task helped overcome the semantic impairment and a clear syntactic impairment was the only one affecting performance. Finally, YO showed impaired performance on both subject and object relative

clause sentences but was found to have an intact score on sentences with a 2 word distance and an impaired score on sentences with a 9 word distance. This results indicate that on top of the syntactic and semantic deficit, YO may also have some form of memory problem affecting his performance. On the Meguvana relative clause comprehension with comprehension questions task all five participants had impaired scores on both sentences with subject and object relatives as well as sentences with similar semantic and phonological NP's.

Summarizing, the five participants that were found to have a profound syntactic deficit were all participants with either an impaired semantic lexicon or impairment in accessing the semantic lexicon. Task analysis seems to show that these impairments affect the comprehension and productions of these individuals also at the sentence level, and that task modality has a big influence for some children on their performance.

9.5 Individuals with only partial data, indicating impaired syntax

Four participants were included in this section although they were unable to complete all the tasks, either due to not understanding task demands or not willing to cooperate. Table 25 shows the background measures for these participants. All four participants were found to have a syntactic deficit that was the most evident in their performance on the definition task. Only one was found to have a co-existing semantic deficit. Conclusions regarding the location of impairment for these participants required a qualitative analysis of their performance. The following section will present this analysis for each of the four individuals.

Table 25. Individuals with partial data: background measures

Participant	Gender	Age	Diagnosis	RPM	CCC	Location of impairment
YA	M	8;6	PDD-NOS	unable to complete task	110	Syntax + phonological output buffer
AM	M	8;9	PDD-NOS	85	127	syntax
NA	M	9;4	PDD-NOS	unable to complete task	125	Syntax, semantic lexicon,

						phonological output buffer
MI	F	10;7	LFA	unable to complete task	113	syntax

Table 26 presents the individual scores of the participants in this group, for the tasks at least one of them was able to complete.

Table 26. individuals with partial data: individual scores

Component tested	Task	YA	AM	NA	MI
Conceptual	Odd one out pictures		90	94	90
	Picture association-pyramids and plam trees			95	92
Semantic lexicon	Written word picture matching	90	95	80	90
	Picture naming	66	88	83	96
Orthographic lexicon	Tiltan Nonword reading	100			
Word reading route including phonological output lexicon	Tiltan single words	60			
Phonological input lexicon	Picture naming phonological errors	3/34	0	3/17	1/12
lexical retrieval route (conceptual-semantic lexicon-phonological output lexicon)	Picture naming semantic errors	9/34	3/12	6/17	6/12
Syntax	Repetition - Global score		61		
	Wh movement		56		
	verb movement		20		
	A movement		93		
	Embedded sentences		100		
	Simple sentence		50		
	Mekayim relative clause comprehension sentence-picture matching Global score (auditory and pictures)				70
	2 word distance				74
	9 word distance				61
	Subject Relative				80
	object relative				58
	Meguvana relative clause comprehension, comprehension questions Global score (auditory)		54	44	
	Subject relative		67	38	
	Object relative		42	50	

	Semantic distracters		38	44	
	Definition task (written word) definition included SR / OR / no R / single words	ungrammatical	SR/ single words	SR / single words	Some OR

All the participants in this group (except YA) completed either one or both of the conceptual component tasks at an age level showing the conceptual component was intact. YA refused to cooperate on these two tasks but based on his score on the word – picture matching and definition task (which showed he had understood all the words) it was concluded that his conceptual component was also intact.

Turning to the tasks testing the semantic lexicon, this group of participants were all able to complete only two tasks- Word picture matching and picture naming. AM and MI had age matched scores on both tasks indicating that their semantic lexicon (as well as phonological input and output lexicons) are intact. YA had an intact score on the word picture matching task but a low score on the picture naming task. His performance on the naming task (66%) was characterized by many semantic and phonological errors as well as errors in which he was not able to access the word itself but was able to produce a gesture indicating a deficit in the phonological output lexicon or access to it from the semantic lexicon. NA had scores that were lower than controls, but were over 80% correct and seemed to be a result of impaired world knowledge. NA also had many phonological errors pointing to a deficit in his phonological output lexicon.

YA was the only participant in this group to complete the Tiltan reading task. On the Tiltan single word reading and word pairs subtests YA had significantly lower scores than his age group controls (60%, 78% respectively) but on the nonword subtest, YA achieved 100% correct, enabling us to conclude that his orthographic input buffer, grapheme phoneme converter, and phonological output buffer are intact. Most of his reading errors were regularization errors indicating that he was reading words via the sub-lexical route, a pattern

that suggests problems in the phonological output lexicon (as was also seen in his naming errors).

Most of the participants were unable / refused to cooperate on the tasks testing syntax. AM was able to complete the repetition task (on which he had impaired scores on sentences with WH movement, verb movement and simple sentences while having intact scores on sentences with A movement and embedded sentences) indicating a specific syntactic deficit. AM also completed the Sentence comprehension task "Meguvana" on which he had low scores on all sentence types. NA was also able to complete this task and achieved a score of 44% correct. In this task the participants heard a sentence with two NP's that one was performing an action on the other. At the end of the sentence a comprehension question was asked and the participants had to name one of the NP's. Most children when making an error on this task produced the wrong NP. NA had made some unique errors that seemed to enforce the idea that his semantic lexicon is impaired, on seven items (out of 27 wrong items) NA produced a noun that had not appeared in the sentence (the man, the woman, the boy – in most cases not related in context) or a perseveration from a previous sentence (the lion). MI was able to complete the sentence picture matching task (Mekayim) but her scores were low on all sentence types.

Finally, all the participants were able to complete the Definition task. This was very surprising as some of these participants were individuals with LFA and yet they understood the task demands. From their definitions it was possible to see that all participants understood the meaning of the word correctly, however, the sentences produced were in many cases ungrammatical, suggesting that the correct word meaning was being accessed but this word meaning could not reach the correct output (ex 27 YA definition).

(26) YA definition example

Target word for definition: טלפון

Telephone

Telephone

Production: זה איפה שמצלצלים

Ze aiefo she-metzaltzelim

'it's where ringing'

NA was able to complete the Definition task by having the words read to him. It was possible to see that he understood all the words in the task, but his definitions were not age matched (included one/ two words) and at times were ungrammatical, indicating a syntactic impairment, and unrelated, indicating a semantic impairment (ex 28).

(27) NA's errors

(28.1)Naming error: unrelated

Target: כובע

Kova

Hat

Production:!מתנה...לא...מדליה...לא...כובע

Matana…lo…medalia…lo…kova!

Present…no…medal…no…hat!

(28.2)Definition error: ungrammatical sentence

Target: בית

Biet

House

Production:בית זה שגרים

Biet ze she-garim

House is that living

Conclusions: wide syntactic impairment

Nine participants were found to have a syntactic impairment that manifested itself in comprehension and production impairments on all sentence types. For the five participants that were able to complete most of the study tasks, it was possible to see that their other impaired components (namely semantics) were interfering in their performance on the syntactic tasks. The Repetition task and the Sentence comprehension (Meguvana) task seemed to be the most sensitive to syntactic impairments while the Definition task was a task that even the participants with overall low functioning abilities were able to complete, enabling us to see part of their impairment that was problematic to test with other tasks.

9.6 Semantic component intact and all other components intact (no impairment)

Out of the 38 ASD participants, 4 were found to have no linguistic or reading impairment. Table 27 shows the background measures these for four participants. All four achieved scores in the normal range both on the RPM and the CCC; in other words, their scores did not differ significantly from those of the corresponding control children.

Table 27. ASD participants with no impairment: background measures

Participant	Gender	Age	Diagnosis	RPM	CCC
TP	M	11.0	Classic Autism	74	147
AL	M	11;3	HFA	105	139
YC	M	12;1	Classic Autism	104	135
PT	M	14;7	HFA	98	148

Each one of these participants scored at an age equivalent level, with few exceptions (Table 28).

Table 28. ASD participants with no impairment: individual scores

Component tested	Task	TP	AL	YC	PT
	Odd one out pictures	100	96	93	87
Conceptual	Picture association – pyramids and plam trees	100	100	100	100
	Odd one out words	96	83	95	100
	Word association- pyramids and plam trees	100	100	81	100
	Word picture matching	95	100	85	85
	Picture naming	97	99	93	92
Semantic lexicon	Semantic homograph reading	100	96	92	100
Orthographic lexicon	Word association- Ma kashur	100	100	97	100
Grapheme phoneme conversion, phonological output buffer	Tiltan Nonword reading	98	100	95	95
Phonological INPUT lexicon	Semantic-phonological word memory	71	86	68	94
	Tiltan single words	94	100	93	94
* phonological errors out of overall errors for participant	picture naming (phonological errors)		1 / 1	1 / 7	1 / 8
	Repetition				
	Global score	94	94	87	93
	Wh movement	88	100	88	88
	verb movement	100	90	80	100
	A movement	100	100	87	100
	Embedded	100	100	100	90
	Simple	100	80	90	90
	Probability Judgment				
	Global score	99	99	94	100
	Wh movement	98	97	90	100
	verb movement	100	100	100	100
	A movement	100	100	90	100
	Embedded	100	100	100	100
	simple improbable	100	100	100	100
	Pronoun agreement judgment				
	Global score %	100	100	97	80
	score part 1	100	100	100	100
	score part 2	100	100	93	60
	Mekayim				
Syntax	Global score	100	100	86	100

	2 word distance	100	100	100	100
	9 word distance	91	91	65	100
	subject relative	100	100	92	100
	Object relative	100	100	78	100
	Meguvana				
	Global score	92	92	81	81
	Subject relative	92	91	87	91
	Object relative	92	91	75	70
	Semantic distracter	88	93	81	75
	Phonological distracter	88	93	87	81
	Definition task (written word) definition included some OR / no R / single words	Some OR	Single words	Some OR	Some OR

TP had ceiling scores on all tasks and was the only participant in this group that had an impaired score on the RPM. AL had perfect scores on all tasks (including the Tiltan reading task, where no errors at all were made) except for one. He scored significantly below control group levels on the Odd one out words subtask. However, error analysis revealed that he consistently choose the leftmost item and thus that in fact his score was a result of lack of cooperation rather than a deficit in the semantic component (as he scored high scores on all other tasks testing the semantic component).YC's scores did not differ from those of age controls on all tasks except on the word subpart of the Association (pyramids and plam trees) task. However, this task was the last task administered for that particular session and YC repeatedly choose only the leftmost item.

PT showed a more complex picture of achievement. He had age equivalent scores on most tasks, but he had scores significantly below age controls on four tasks. On the Odd one out picture part, his score was significantly lower than the control group (87% correct). However, this score was high in absolute terms, and thus we can deduce PT had understood the task and that he generally didn't have trouble differentiating between items. Error analysis revealed that all of PT's errors were on items belonging to a close semantic category and that all of them were made towards the end of the task, hence pointing at fatigue to be the reason

for the lower score. On the Word-picture matching task, Pronoun agreement judgment task, and on the Sentence comprehension task PT's scores were significantly lower than control scores (Word-picture matching task: 85%; Pronoun agreement judgment: 80%; Sentence comprehension: 81%). Error analysis found that in all three tasks, errors were mainly made towards the end of the task, again pointing to fatigue as being the reason for lower scores. On the Tiltan reading task, on the Non-word reading and pairs of words reading subparts PT's scores were age equivalent. On the single word reading subpart his score was below the cut-off score for his age (98% correct), although still a relatively high score (94%). Error analysis found that most of his errors were errors typical of Surface dyslexia (a deficit in the lexical route which forces the reader to read aloud via the sublexical route), Vowel letter dyslexia (a problem with processing vowels that is seen in errors of omission, substitution, transposition and addition of vowel letters) and lexical substitutions. The fact that PT’s error rates were relatively low and that his overall reading scores were generally age equivalent argue that his profile corresponds to that of the unimpaired group.

In summary, four participants were determined to have a profile in which there is neither language nor reading impairment, in any area. Three participants with this profile were within norms in terms of NVIQ and the CCC, one had a low NVIQ score but his CCC score was within norms. Any low scores observed were argued to be the result of fatigue or lack of cooperation, as evidenced by error analysis (selection of the answer located in the same position throughout the task, or errors occurring only at the end of the task).

9.7 Intact semantics, intact syntax impaired pragmatics and dyslexia

One participant (TY) was found to have intact performance on the conceptual tasks, intact semantic lexicon and intact syntax but impaired pragmatic understanding of the tasks and dyslexia. Table 29 presents TY's background measures.

Table 29. TY bacground measures

Participant	M/F	Age	Diagnosis	RPM	CCC	Location of impairment
TY	M	11;5	Classic Autism	78	139	Dyslexia

As seen in Table 30, TY's conceptual component, semantic lexicon and syntax were intact. On two tasks (reading and paraphrasing heterophonic homographs and the repetition task) he had low scores that were a result of not understanding the task demands and seemed to be pragmatic in nature based on his performance. On the reading tasks TY had many morphological errors and errors of letter substitutions. Together with his good sentence repetition (once he figured out what he had to do it that task), we concluded that these errors originated in a deficit in the orthographic input buffer. His regularization errors in reading aloud alongside his very good performance in the written homophone comprehension task indicated that TY had an inter-lexical surface dyslexia. His low performance on the pronoun agreement task, which was presented in writing, seem to be a result of his reading deficit.

Table 30. TY task scores

Component tested	Task	TY
Conceptual	Odd one out pictures	90
	Picture association –pyramids and plam trees	97
Semantic lexicon	Odd one out words	96
	Word association – pyramids and plam trees	89
	Word picture matching	95
	Picture naming	96
	Semantic homograph reading	100
Orthographic lexicon	Word association – Ma kashur	98
Grapheme phoneme conversion, phonological output buffer	Tiltan Nonword reading	83
Phonological input lexicon	Semantic-phonological word memory	82
Word reading route including phonological output lexicon	Tiltan single words	88
* phonological errors out of overall errors for participant	picture naming (phonological errors)	0
Syntax	**Repetition** Global score	87
	Wh movement	88

	verb movement	90
	A movement	93
	Embedded sentences	70
	Simple sentence	90
	Probability Judgment Global score	96
	Wh movement	93
	verb movement	100
	Embedded sentences	100
	Simple sentence	100
	Simple improbable	100
	Pronoun agreement judgment Global score	80
	score part 1	80
	score part 2	80
	Mekayim relative clause comprehension sentence-picture matching Global score	91
	2 word distance	96
	9 word distance	78
	Subject relative	100
	object relative	79
	Meguvana relative clause comprehension, comprehension questions Global score	94
	Subject relative	100
	Object relative	88
	Semantic distracters	94
	Phonological distracters	94
	Definition task (written word) definition included SR / OR / no R / single words	Some OR

9.8 Conclusion

This study set out to test the semantic abilities of children with ASD. Only five participants were found to not have a semantic or syntactic related impairment and had age matched scores on all linguistic, reading and memory tasks. Two different semantic related impairments were found: impairment in the semantic lexicon itself and impairment in access to the semantic lexicon. In all cases of impaired semantics (or access to semantics), the syntactic component (or access to it) was also found as impaired. Two types of syntactic impairment were found: WH movement impairment with impaired scores on complex

sentences but intact scores on simple sentences, and a wide syntactic impairment with low scores on all sentence types. Only a small group of participants with an impaired syntactic component also had an impaired semantic lexicon indicating that a syntactic deficit was independent of a semantic deficit and much more frequent. Of the 38 ASD participants, none was found to have an impaired conceptual component, including the participants that were diagnosed as LFA.

Discussion

The aim of this study was to investigate lexical semantics in children and adolescents with ASD, for which previous research has found highly conflicting results. Our review of previous studies found that different studies tested lexical semantics using different tasks and that the characteristics of the participants with ASD also varied widely from study to study for NVIQ, VIQ, language impairment and diagnostic classification, with the majority of studies focusing on children with HFA. All of these elements have made it hard to reach conclusions regarding the population as a whole, except that semantic abilities may be indicative of broader language abilities in children with ASD. Although results regarding the exact nature and depth of semantic impairment (or abscent of impairment) in most children with ASD are still inconclusive, lexical semantics continues to be one of the most commonly used measures of linguistic competence in studies including assessment of language in children with ASD.

In the following, we discuss how the results from this study bear on each of our initial research questions, integrating results reported in previous studies. Section 10.2 will discuss study limitations and as well as clinical implications and directions for future research.

10.1 Research questions

Is the semantic component impaired in children with ASD?

Some previous studies have found participants with ASD to achieve scores on semantic tasks that were below chronological age performance (for example: Battagalia, 2012; Boser et al., 2002; Lofkvist et al., 2014; McGregor et al., 2012; Norbury 2005). Based on these findings, we hypothesized that at least some children in our sample would display a deficit in their semantic component. We sought to confirm the findings of these previous studies, but also to see how widespread this profile is in children with ASD. Out of the 38 ASD participants, 11 were found to have an impaired semantic component and 3 participants were found to be impaired in accessing the semantic component. Together, this amounts to

roughly one-third of participants with impaired lexical semantics. Out of these 14 participants, none were found to have an exclusive semantic impairment, in all cases a semantic impairment was found together with at least one other impaired location.

These results are in line with previous studies that seem to show that impaired lexical semantics is part of a wider linguistic deficit (Kjelgaard & Tager-Flusberg, 2001; McGregor et al., 2012; Modyanova et al., 2017; Tuller et al., 2017; Whitehouse et al., 2008). Our review of previous studies showed a pattern that children with ASD that were found to have impaired lexical semantics seemed to have other variables impaired, pointing to a broader linguistic or cognitive deficit. Our results show that a deficit in semantics seems to appear together with other linguistic deficits making it hard to differentiate whether the semantic impairment is a primary impairment or whether it is secondary and a result of other linguistic abilities that have had an influence on lexical semantic development. Previous studies that have found children with ASD to exhibit semantic deficits have usually been very narrow in testing other linguistic abilities and so we cannot be certain if these children also exhibited broader linguistic impairment as seen here, or if they had an exclusive semantic impairment.

Does the explicitness / implicitness of semantic tasks influence performance?

One of this study's hypotheses was that the more explicitly the task demands are on accessing the semantic component, the more likely that children with ASD will have better performance. We reasoned this because previous research (for example Kissine et al., 2015) found that although children with ASD may understand an indirect instruction, their comprehension is far better when told to listen for indirect instructions. In order to test this reasoning, tasks were divided into four categories based on how explicitly the task demands were on accessing semantics (meaning). A significant difference was found in favour of the more explicit tasks, which appears to support our initial hypothesis. However, these results should be addressed with caution. This is because the category corresponding to the most

explicit access to semantics was in fact based on only one score from the Definition task, the score for understanding the word; most participants with ASD scored at ceiling levels for this. On the other hand, most participants with ASD produced very poor definitions, but this seemed to be more because of their syntactic deficit and less because of their pragmatic/semantic abilities. When we compared the explicit/ implicit task categories by using the composite score from the Definition task, all significant differences between categories disappeared, indicating that the difficulties in the Definition task were syntactic in nature rather than about accessing semantics. For the rest of the tasks, this kind of division was not possible and thus it is unclear what had greater influence on the results, the explicitness of the task or the degree of syntactic abilities needed to correctly complete it.

Although our results regarding whether the task included explicit reference to semantics were inconclusive, it was possible to see that task modality, the way a task was administered, influenced both participant motivation and performance. Most participants did significantly better on tasks with pictures and reading than on tasks which included only auditory stimuli.

Does impairment in the semantic component affect syntactic performance, or can the syntactic component be impaired independently?

One of the main results of this study is that out of 38 participants with ASD, 33 were found to have a syntactic deficit. Two syntactic profiles were found, the first was a profile of impaired performance on complex syntactic structures (namely WH movement, object relatives) together with intact performance on sentences with less complex structures (simple sentences, subject relatives). This pattern of impairment is commonly found in other language pathologies and we believe that this profile corresponds to the children that past studies have identified as having a syntactic impairment similar to SLI. The second profile of impaired syntax that was found was of children with ASD that had low scores on all sentence types, in both comprehension and production. This group of children also all had an impaired semantic

lexicon or impaired access to semantics. It is thus likely that the semantic impairment may be influencing syntactic comprehension and production in these children. A small group of children with low functioning abilities as defined by either below normal performance on RPM or inability to complete this task (though not all of these had a formal diagnosis of LFA) were able to complete only a small number of tasks. Most of these children were able to complete the Definition task and this provided invaluable insight into their syntactic abilities. The Definition task showed impaired syntactic performance for these participants, but intact semantics. Their productions showed they were able to understand all of the words, even though these productions revealed clear syntactic impairment. The Definition task constituted an important tool in differentiating between the effect of different impairments, as the nature of the definition produced hinted to the source of impairment.

Based on previous studies it is hard to determine what the rate of syntactic impairment is in children with ASD as most studies used LN/LI as an inclusion criterion and so ASD participants were not randomly recruited. Moreover, many studies used a measure of lexical semantics as a proxy for overall language, implying an automatic relationship between lexical semantic level and, for example, level in syntax. While many of the children in this study that had impaired syntax also exhibited impaired semantic abilities (n = 14), most of them did not (n = 19). This dissociation has profound implications for studies that have used only lexical semantics as an indication of overall linguistic abilities. This result is in line with Tager-Flusberg's (1986) Semantic deficit hypothesis wherein she claims that a semantic deficit will affect acquisition of all other linguistic areas, especially syntax. Our results contradict Naigles' (2002) 'Form is easy meaning is hard' hypothesis, wherein it was argued that children with ASD should have a hard time acquiring meaning, as meaning is involved in gathering information from others and resulting in deficits in semantics, while the structural part of language should be easy and unimpaired in most children with ASD. Our study found the

opposite to be true: most participants with ASD had good semantic abilities, even those who had a syntactic deficit.

Previous research with aphasic participants had found a double dissociation between impaired syntax and semantics (Ellenblum, 2013): some participants displayed impaired syntax, but intact semantics, while others displayed intact syntax and impaired semantics. This was not the case in the present study of children with ASD, which found only a single dissociation: children with syntactic impairment, but intact lexical semantics. No participant had impaired lexical semantics without impaired syntax, some also had an additional impairment such as dyslexia or impairment in the phonological lexicons.

As part of testing the different parts of the Lexical retrieval model and the Dual route to reading model, apart from syntax, we also tested phonological components and reading abilities. In line with previous studies that tested phonological abilities in children with ASD (such as Kjelgaard & Tager-Flusberg, 2001), this study found that the majority of participants with ASD had good phonological abilities, as tested by the Semantic phonological word memory task ("Probe"), the Sentence repetition task, Sentence comprehension (Similar semantic/ phonological NP “Meguvana”) task, and the Tiltan reading tasks. Moreover, phonological errors were rarely found on the Picture naming task and the Definition task. Four participants were found to have phonological deficits and these were located in either the phonological output or input lexicons (or both). None of these four participants was found to have an exclusive phonological impairment; all had at least one other component impaired (one in syntax, one in syntax and reading and one had all components impaired except the conceptual component.). In order to determine the prevalence of impaired phonology in children with ASD, not the object of our study or of most previous studies, it would be crucial that complex aspects of phonology be specifically targeted (see Tuller et al., 2016), in a way that complex syntax was targeted in the present study.

In regard to the participants reading abilities, our results found that eight participants had a form of dyslexia. In line with previous studies that have reported good decoding skills in children with ASD and poor comprehension, we found that many participants had higher scores on the nonword reading subtest compared to reading of single words, which seems to be a frequent profile (at least in this particular group of participants with ASD).

We have addressed our results in terms of associated deficits. The question of effect is one that we have not been able to answer as it is unclear what is affecting what. In the children studied here, semantic impairment was always found with a syntactic impairment and at times with other impaired components as well. In some cases when the error patterns were consistent it was possible to see that the semantic deficit was influencing syntactic performance, and in fact the participants who had both semantic and syntactic low scores seemed to show a much wider syntactic deficit than the participants who were only impaired in syntax.

10.2. Limitations, clinical implications and directions for future research

This study has limitations. The first concerned the children who we found had not cooperated on several tasks (pointing to pictures appearing on the left side, for example). In many case, these behavioural patterns were observed only when the data was analysed, after testing had finished. It would have been ideal to administer the task again or to administer a similar task testing the same components. The same is true for the children found to have a dyslexic pattern in the Tiltan screening test. Although for most of them we were able to conclude their dyslexia type, for some, further tasks would have shed better light on their reading impairment.

A final limitation concerned background measures for the participants with ASD. Some background measures available in children's medical records (MLU, WISC, CARS, SCQ, ADIR/ADOS), and especially general IQ scores, could not be included in this study

because of regulations governing research on school children in Israel. Given the large number of tasks involved in our study, it was impossible to add more tests to these same children. Clearly though it would be very important for future research on Israeli children with ASD to include such measures in order to identify more precisely subgroups of children with ASD.

Turning to the clinical implications of this study, we would first like to return to the way children are diagnosed with ASD today in Israel (and in many places around the world). The list of evaluation tests that a clinician can use and the diagnostic procedure in Israel is very clear. The tests are normed and test a wide range of intellectual, motor and daily living abilities. None of these tests evaluates syntax at an older age. The two tests that are language oriented are the MLU (used up to 36 months) and the Bayley (used up to 42 months). The Wechsler intelligence test also has a language part in it that assess: similarities (how two words are similar), definition task (in which the guidelines are mainly pragmatically focused), general knowledge questions, comprehension questions about social situations or common concepts and a naming task that mainly tests naming speed with no error analysis. Children with ASD are sent for a re-evaluation every three years up until age seven. This means that their linguistic abilities will be tested only on the first diagnosis (usually around 24 months), and then only using the Wechsler intelligence test, if at all. While the Wechsler intelligence test may be a good intelligence test, judging by the tasks used, it is certainly not be linguistically sensitive enough to detect the syntactic problems that according to our research results are fairly common in children with ASD.

The definition task and the repetition task seemed to be the most sensitive tasks to syntactic impairment, the definition task was completed by 37/38 ASD participants, some with LFA that were unable to understand task demands of any of the other syntactic tasks and the Sentence repetition task showed impaired performance even for HFA participants who

were able to achieve high scores on all other syntactic tasks. Future studies could profitably test a bigger group of children and adolescents with ASD in order to be able to achieve group conclusions as well as be able to establish clinical markers differentiating the linguistic errors made by children with ASD and other language related pathologies.

For some children, reading was a big obstacle and it seems that some of the ASD participants also have dyslexia. We were unable to find current research testing the rate of children with ASD and dyslexia. In most previous studies poor reading skills were attributed to poor linguistic skills, but a separate screening for dyslexia was not performed. Reading and ASD appears to be an under-researched area.

One of the results of our study was that task modality may have a big influence on performance in children with ASD. Future research should take into account that whether a task is presented with pictures, entails reading or has only auditory stimuli could have an influence on results; these variables should be controlled for as well as study protocol should try to contain a variety of modalities, as was done in this study.

The high prevalence of impaired syntax and the existence of dyslexia observed in our results are important when considering treatment and speech-language therapy programs for children with ASD. To our knowledge, in Israel, there are no special programs or designated syntactic assessment tools that target improving syntactic skills in children with ASD and there is no specific educational program targeted at teaching children with ASD to read (though there is one for children with hearing impairment or cognitive disabilities).

As with former studies, this study also found very great variability in the performance of the participants with ASD; group conclusions should therefore be interpreted with caution. This having been said, two clear findings emerged that have straightforward consequences for how language is measured in research on ASD. Only a minority of the children with ASD in our sample had a semantic deficit, while the vast majority had a syntactic deficit. This

questions the widespread use of lexical semantics as a proxy for language in ASD research. Our results highlight the importance of testing a wide range of linguistic abilities in children with ASD as well as performing in-depth error analyses of their performance.

General summary and conclusion

Lexical semantics is one of the most widely used indications for overall linguistic abilities in studies with ASD participants. Past studies have been inconsistent in their findings regarding lexical semantics abilities of children with ASD, but there seems to be a reoccurring pattern of impaired lexical semantics within a wider linguistic or cognitive deficit.

The Lexical retrieval model and the Dual route to reading model were used for the first time with ASD participants in this study. A comprehensive language assessment was made for each individual with tasks corresponding to performance on the different components of these models. Accuracy scores and in-depth error analysis was made and compared to age equivalent TD children.

Results found about one third of the participants had a semantic impairment, of these all had a syntactic impairment, some also had dyslexia, but none had a selective semantic impairment. Most of the participants in this study (33/38) were found to have a syntactic impairment, but of these less than half had a semantic one, revealing a dissociation between the semantic lexicon and syntax, but not the other way around as a semantic deficit always appeared with a syntactic one.

The Definition task was found to be one of the most sensitive tasks both for semantic and syntactic deficits, since even children with LFA were able to complete it. Performance on the Naming task (different versions of which are frequently used to test lexical semantics) was found to be intact in most children with a syntactic impairment, and even for some that were found to have a semantic impairment, error analysis was needed in order to uncover their deficit. These results question the efficiency of the wide use of lexical semantics in general and picture naming in particular in studies with children with ASD as an indication of linguistic abilities, while pointing to the existence of a variety of lexical semantic-language

profiles in this population. This study's results highlight the importance of using a wide range of linguistic tasks in assessing language in children with ASD, to overcome cooperation issues as well as different task modality issues and to make it possible to differentiate between different sources of impaired performance.

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Appendix

Appendix 1 Task summary

	Task name	Built for this study or taken from the study by:	Task Description	Part of the model tested	Answer analysis
1	Odd one out pictures	Built for this study based on the task by Friedmann (2001).	the participant was shown four pictures on a computer screen and was asked to point to the one picture that was different	conceptual system	correct answers were counted and error analysis made.
	Odd one out words	Built for this study based on the task by Friedmann (2001).	participants were shown four words on a computer screen, and were asked to read them to themselves and then point to the one that was "unrelated". The word part included the same objects that had appeared in the picture part, except for the shapes stimuli.	conceptual system, the semantic lexicon, orthographic-visual analysis & orthographic input buffer, and the orthographic input lexicon	correct answers were counted and error analysis made.
2	Association task - Pyramids and palm trees - pictures	Biran and Friedmann (2007).	participants were presented with three images. The target image shown at the top of the page (ear) and two pictures displayed at the bottom in equal spaces (necklace, earrings). The participant was asked to look at the top picture and then point to the most appropriate picture that was related to it between two bottom pictures that appeared in equal spacing. 35 threesomes were presented.	concepual system	correct answers were counted.
	Association task - Pyramids and palm trees - words	Biran and Friedmann (2007).	participants were presented with word threesomes. The target word was presented at the top of the page (ear) and two words displayed at the bottom in equal spacing (necklace, earrings). The participant was asked to read the three words aloud and to point to the most appropriate lower word that matches the upper word. 35 threesomes were presented, the first 25 were the same words as in the pictures part and the last 10 threesomes included abstract words	conceptual system, the semantic lexicon, orthographic-visual analysis & orthographic input buffer, and the orthographic input lexicon	correct answers were counted.
3	Semantic phonological word memory – "probe"	Friedmann & Gvion (2002)	participant heard lists of eight, two-syllable words that were varied in frequency, in the possibility to imagine them and in their lexical and semantic affiliation. The participant heard first an uninterrupted list of eight words at a rate of a word per second and after that a second list of eight words where he was asked to state for each word whether it had appeared on the first list or not. In the second list, half of the items were items that had appeared on the first list and the other half included semantic and phonological distracters (car/vehicle, chalon (window)/balon (balloon)).Each participant heard a total of 20 lists	Phonological input buffer, phonological input lexicon, semantic lexicon and conceptual system	correct answers were counted and error analysis made on mistake types (semantic or phonologic)
4	Sentence repetition task - "Petel"	Friedmann, (2000)	The participant was asked to listen to a sentence, loudly count to three and then repeat the sentence exactly as he heard it. The participant was asked to count to three so as to prevent phonological memorization in the phonological loop (Baddeley, 1997) and hence automatic repetition. The task consisted of 70 sentences	phonological output buffer, phonological lexicon, conceptual system, semantic lexicon, phonological output lexicon, phonemic output buffer and syntax	correct answers were counted and error analysis made according to sentence type, and mistake type (structural error or lexical error).
5	Sentence comprehension- Similar semantic/ phonological NP – "Meguvana"	Friedmann and Novogrodsky (2002) "Bambi" battery.	The participant heard 48 sentences, for each sentence he was asked to listen carefully and then answer a question regarding one of the participants.	Phonological output buffer, phonological lexicon, conceptual system, semantic lexicon, phonological output lexicon, phonemic output buffer and syntax	correct answers were counted and error analysis made on mistake types (semantic or phonologic)
6	Semantic-syntactic reactivation sentence-picture matching –	Based on the task by Friedmann and Gvion (2003)	The participant was presented with two pictures side by side on a computer screen. Each picture included two figures, one figure performing an action on the other. One picture matched the target sentence and the second depicted reversed roles with the same characters. Before hearing the target sentence,	Phonological input buffer, phonological input lexicon, conceptual system, semantic lexicon and syntax	correct answers were counted.

	"Mekayim"		participants were asked to identify the characters in the pictures. Then they were asked to listen carefully to a sentence and point to the picture that matched the sentence heard. The participant heard 44 sentences with semantically reversible relative clauses that were split into two parts, each part administered at a different session. Half of the sentences included two words between the antecedent and the gap and half included nine words between the antecedent and the gap.		
7	Pronoun agreement judgment	Based on Friedmann (1998)	The participant was shown two sentences side by side. One sentence was correct grammatically and the second was not. The participant was asked to circle or point to the sentence he thought was "not good" and then explain why he thought it was not a grammatical sentence. This task had two parts; each part was administered at a different session. The first part of the test included sentences with verb movement; the ungrammatical sentences were sentences that the antecedent after the trace appeared again instead of disappearing. Both sentences included the same verbs and participants. In the second part of the test both sentences had the same sentence structure, but the verb and the verb complements (?) were synonyms and not matched in gender.	Phonological input buffer, phonological input lexicon, conceptual system, semantic component, syntax, Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon	correct answers were counted.
8	Plausibility judgment	Built for this study	Each participant was shown a sentence on a computer screen and was asked to say if this sentence "could be true" or not. If not he was asked to explain why not. If the participant had good reading abilities (as assessed by the Tiltan word reading task), he was asked to read the sentence, if not the sentence was read to him. If it seemed that because of incorrect reading the participant misunderstood the sentence it was read to him again. The task consisted of 6 different sentence types – each type containing 6 pairs of plausible and implausible sentences. The sentence types matched the sentence types that appeared in the repetition task so that it would be possible to control the participant's comprehension and production	Phonological input buffer, phonological input lexicon, conceptual system, semantic component, syntax, Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon	correct answers were counted
9	Word Picture matching – "Pilpel"	Built for this study	The participants were shown a computer screen that had a word written at the top, below the word were 8 pictures including the target picture and 7 more pictures from the same or a close semantic category. Participants were asked to read the word out loud and point to the matching picture. Participants who had low scores on the Tiltan reading test were read the word by the experimenter and asked to point to the correct picture	conceptual system, semantic lexicon, Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon	correct answers were counted and error analysis made on mistake types
10	Word association task – Ma Kashur	Biran & Friedmann (2007)	The task included 40 triads; each triad contained a target word (placed at the top of the screen) and two words (placed at the bottom of the screen with equal distance from each other and from the target word above). One word was associated semantically with the target word and the other word was a homophone or a potentiophone of the associated word. The participants were asked to read the target word and then point to the word which was semantically associated to the target word	Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon	correct answers were counted.
11	Comprehension of mental verbs	Eilon (n.d)	Participants were shown a short printed story that was read aloud by the experimenter. At the end of the story the participant was shown three options of mental verbs that could complete the last sentence starting with a description of the mental or emotional behavior of the character. Participants	Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological input buffer and lexicon, semantic lexicon and	correct answers were counted and error analysis made according to distractor type.

			were asked to choose the most correct option	conceptual system	
12	Reading test - Tiltan	Friedmann & Gvion, (2003)	The participants were shown 136 single words, 30 non-words and 30 pairs of words.The participant was asked to read these words aloud as accurately as possible with no time constrain.	orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer	correct answers were counted and error analysis made according to Friedmann & Gvion, (2003)
13	Reading and paraphrasing of relative clauses with a heterophonic homograph embedded	Friedmann and Gvion, (2003)	After reading the sentence the participant was asked to explain it in his own words, this was done in order to test what the participant had understood from the text and if the participant was able to access the information he had just read. The task included 20 sentences with a central verb that is a hetrophonic homograph of a noun. Each one of the ten homographs appeared in two sentences – once in a sentence with a relative clause and once in a simple sentence with no verb movement and equally long. The relative clause sentences were object relative sentences with a central subjugation where the homograph appeared as a verb at the position right after the trace.	Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer	Correct responses were counted for correct reading of the homograph and quantitative analysis was done on the paraphrasing part. Participants who were unable to complete the Tiltan reading test were not administered this task.
14	Reading of sentences with a two meaning noun homograph	Sukenik (n.d.)	Participants were asked to read heterophonic homographs that were incorporated in sentences that biased their meaning towards only one reading. The sentences were all simple sentences and the hetrophonic homographs that were used were all noun-noun homographs that in order to read them correctly the participant had to understand the meaning of the sentence and the meaning of the word that would most likely be relevant to the context. The participants were asked to read the sentences aloud with no time limit	Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer	Correct responses were counted for correct reading of the homograph
15	Word definition	Friedmann, Aram & Novogrodsky, 2011	Each participant was presented with a single word on a computer screen. The participant was asked to read the word aloud and then explain its meaning. Participants were presented with 30 words including nouns, verbs and emotions.	Orthographic-visual analysis & orthographic input buffer, orthographic input lexicon, phonological output lexicon and phonemic output buffer	Answer analysis was done according to the definition provided to determine whether the participant understood the meaning of the word, was the definition appropriately pragmatic (ie whether another person could understand what the word in question was) and whether the participants understood the target word. Participants who did not complete the Tiltan reading test were shown the words on the screen and the word was read to them.
16	Picture naming “Shemesh”	Biran and Friedmann (2004)	Participants were shown 100 pictures of nouns. Each picture appeared on a computer screen which displayed a single image.The participant was asked to name the image. There was no time limit and the participant was told that he should say the first word that he was thinking of.	conceptual system, semantic lexicon, phonological output lexicon and phonemic output buffer	Correct responses were counted and mistake analysis was done according to the categories made in the study by Sukenik and Friedmann (2012).

Appendix 2 Task correlation with age

	Age
Clear correlations	
Tiltan – single word reading	r = .351, p = .049
Tiltan – word pairs	r = .368, p = .042
Word association –Ma kashur	r = .543, p = .002
RPM – raw score	r = .558, p = .001
RPM – standard score	r = .366, p = .043
Odd one out – words	r = .486, p = .006
Plausibility judgment	r = .497, p = .007
Picture naming	r = .387, p = .016
Mental verb comprehension	r = .439, p = .009
Reading and paraphrasing of relative clauses with a heterophonic homograph embedded	r = .494, p = .005
Reading of sentences with a two meaning noun homograph	r = .529, p = .003
Pronoun agreement judgment	r = .538, p = .003
Semantic-syntactic reactivation sentence-picture matching – “Mekayim"	r = .559, p = .001
Tendency	
Sentence repetition task - “Petel”	r = .327, p = .073
Picture association	r = .328, p = .051
Semantic phonological word memory – “probe”	r = .334, p = .119
NO correlation	
CCC total score	r = .270, p = .101
CCC pragmatic score	r = .298, p = .069
Word association	r = .264, p = .158
Sentence comprehension-Similar semantic/ phonological NP – “Meguvana”	r = .279, p = .122
Tiltan – nonword reading	r = .250, p = .174
Word picture matching	r = -.006, p = .972
Odd one out pictures	r = .168, p = .326
Word definition correct reading	r = -.062, p = .725
Word definition pragmatic answer	r = .118, p = .486

Appendix 3 Inter task correlations

3.1 Inter task correlation – conceptual tasks

		Odd one out pictures	Picture association-pyramids and palm trees
Odd one out pictures	Pearson Correlation	1	0.257
	Sig. (2-tailed)		0.135
	N	36	35
Picture association-pyramids and palm trees	Pearson Correlation	0.257	1
	Sig. (2-tailed)	0.135	
	N	35	36

3.2 Inter task correlation – semantic tasks

		Word picture matching	Odd one out words	Word association pyramids and palm trees	Picture naming	Sentence reading with a noun homograph
Word picture matching	Pearson Correlation	1	0.314	0.323	.557**	0.357
	Sig. (2-tailed)		0.091	0.082	0.000	0.053
	N	38	30	30	38	30
Odd one out words	Pearson Correlation	0.314	1	.634**	.525**	.615**
	Sig. (2-tailed)	0.091		0.000	0.003	0.000
	N	30	30	30	30	30
Word association pyramids and palm trees	Pearson Correlation	0.323	.634**	1	.660**	0.284
	Sig. (2-tailed)	0.082	0.000		0.000	0.128
	N	30	30	30	30	30
Picture naming	Pearson Correlation	.557**	.525**	.660**	1	0.303
	Sig. (2-tailed)	0.000	0.003	0.000		0.103
	N	38	30	30	38	30
Sentence reading with a noun homograph	Pearson Correlation	0.357	.615**	0.284	0.303	1
	Sig. (2-tailed)	0.053	0.000	0.128	0.103	
	N	30	30	30	30	30

3.3 Inter task correlation – syntactic tasks

		Sentence repetition	Plausability judgment	Reading and paraphrasing of relative clauses with a heterophonic homograph-homograph reading	Grammaticality judgment	Semantic-syntactic reactivation sentence-picture matching	Sentence comprehension - Similar semantic/ phonological NP
Sentence repetition	Pearson Correlation	1	.662**	.530**	0.206	.549**	.624**
	Sig. (2-tailed)		0.000	0.003	0.292	0.002	0.000
	N	31	28	30	28	30	31
Plausability judgment	Pearson Correlation	.662**	1	.537**	.687**	.823**	.654**
	Sig. (2-tailed)	0.000		0.003	0.000	0.000	0.000
	N	28	28	28	27	28	28
Reading and paraphrasing of relative clauses with a heterophonic homograph-homograph reading	Pearson Correlation	.530**	.537**	1	.379*	.688**	.419*
	Sig. (2-tailed)	0.003	0.003		0.047	0.000	0.021
	N	30	28	30	28	30	30
Grammaticality judgment	Pearson Correlation	0.206	.687**	.379*	1	.569**	.466*
	Sig. (2-tailed)	0.292	0.000	0.047		0.002	0.012
	N	28	27	28	28	28	28
Semantic-syntactic reactivation sentence-picture matching	Pearson Correlation	.549**	.823**	.688**	.569**	1	.592**
	Sig. (2-tailed)	0.002	0.000	0.000	0.002		0.001
	N	30	28	30	28	31	30
Sentence comprehension - Similar semantic/ phonological NP	Pearson Correlation	.624**	.654**	.419*	.466*	.592**	1
	Sig. (2-tailed)	0.000	0.000	0.021	0.012	0.001	
	N	31	28	30	28	30	32

Appendix 3.4 - Inter task correlation reading tasks

		Tiltan single words	Tiltan nonwords	Tiltan pairs	Word Association (Ma Kashur)	Odd one out words	Word association pyramids and palm trees	Plausability judgment	Mental verb comprehension	Reading and paraphrasing of relative clauses with a heterophonic homograph-homo reading	Sentence reading with a noun homograph	Pronoun agreement judgment
Tiltan single words	Pearson Correlation	1	0.272	.853**	.756**	.736**	.482**	.437*	.606**	0.261	.698**	0.250
	Sig. (2-tailed)		0.139	0.000	0.000	0.000	0.007	0.020	0.000	0.163	0.000	0.199
	N	32	31	31	30	30	30	28	31	30	30	28
Tiltan nonwords	Pearson Correlation	0.272	1	.388*	.459*	0.274	0.306	.545**	.441*	.553**	.506**	0.149
	Sig. (2-tailed)	0.139		0.031	0.011	0.144	0.100	0.003	0.015	0.002	0.004	0.450
	N	31	31	31	30	30	30	28	30	30	30	28
Tiltan pairs	Pearson Correlation	.853**	.388*	1	.701**	.525**	0.302	.479**	.395*	0.212	.656**	0.165
	Sig. (2-tailed)	0.000	0.031		0.000	0.003	0.105	0.010	0.031	0.261	0.000	0.402
	N	31	31	31	30	30	30	28	30	30	30	28
Word Association (Ma Kashur)	Pearson Correlation	.756**	.459*	.701**	1	.612**	.529**	.691**	.647**	.490**	.780**	.490**
	Sig. (2-tailed)	0.000	0.011	0.000		0.000	0.003	0.000	0.000	0.006	0.000	0.008
	N	30	30	30	30	30	30	28	30	30	30	28
Odd one out words	Pearson Correlation	.736**	0.274	.525**	.612**	1	.634**	.469*	.678**	0.327	.615**	.403*
	Sig. (2-tailed)	0.000	0.144	0.003	0.000		0.000	0.012	0.000	0.077	0.000	0.034
	N	30	30	30	30	30	30	28	30	30	30	28

Word association pyramids and palm trees	Pearson Correlation	.482**	0.306	0.302	.529**	.634**	1	0.254	.438*	0.290	0.284	0.206
	Sig. (2-tailed)	0.007	0.100	0.105	0.003	0.000		0.192	0.016	0.120	0.128	0.294
	N	30	30	30	30	30	30	28	30	30	30	28
Plausability judgment	Pearson Correlation	.437*	.545**	.479**	.691**	.469*	0.254	1	.642**	.537**	.713**	.687**
	Sig. (2-tailed)	0.020	0.003	0.010	0.000	0.012	0.192		0.000	0.003	0.000	0.000
	N	28	28	28	28	28	28	28	28	28	28	27
Mental verb comprehension	Pearson Correlation	.606**	.441*	.395*	.647**	.678**	.438*	.642**	1	.495**	.576**	0.341
	Sig. (2-tailed)	0.000	0.015	0.031	0.000	0.000	0.016	0.000		0.005	0.001	0.076
	N	31	30	30	30	30	30	28	34	30	30	28
Reading and paraphrasing of relative clauses with a heterophonic homograph-homo reading	Pearson Correlation	0.261	.553**	0.212	.490**	0.327	0.290	.537**	.495**	1	.599**	.379*
	Sig. (2-tailed)	0.163	0.002	0.261	0.006	0.077	0.120	0.003	0.005		0.000	0.047
	N	30	30	30	30	30	30	28	30	30	30	28
Sentence reading with a noun homograph	Pearson Correlation	.698**	.506**	.656**	.780**	.615**	0.284	.713**	.576**	.599**	1	.389*
	Sig. (2-tailed)	0.000	0.004	0.000	0.000	0.000	0.128	0.000	0.001	0.000		0.041
	N	30	30	30	30	30	30	28	30	30	30	28
Pronoun agreement judgment	Pearson Correlation	0.250	0.149	0.165	.490**	.403*	0.206	.687**	0.341	.379*	.389*	1
	Sig. (2-tailed)	0.199	0.450	0.402	0.008	0.034	0.294	0.000	0.076	0.047	0.041	
	N	28	28	28	28	28	28	27	28	28	28	28