UNIVERSITY OF BIRMINGHAM

University of Birmingham
Research at Birmingham

Receptive language is associated with visual perception in typically developing children and sensorimotor skills in autism spectrum conditions

Hannant, Penny

DOI:
10.1016/j.humov.2018.03.005

License:
Creative Commons: Attribution-NonCommercial-NoDerivs (CC BY-NC-ND)

Document Version
Peer reviewed version

Citation for published version (Harvard):
Hannant, P 2018, 'Receptive language is associated with visual perception in typically developing children and sensorimotor skills in autism spectrum conditions', *Human Movement Science*, vol. 58, pp. 297-306. https://doi.org/10.1016/j.humov.2018.03.005

Link to publication on Research at Birmingham portal

Publisher Rights Statement:
Checked for eligibility: 02/08/2019

General rights
Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

•Users may freely distribute the URL that is used to identify this publication.
•Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
•User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
•Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy
While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Download date: 26. Apr. 2024

Receptive Language is Associated with Visual Perception in Typically Developing Children and Sensorimotor Skills in Autism Spectrum Conditions.

Penelope Hannant[1][2]

[1]Centre for Research in Psychology, Behaviour and Achievement, Coventry University, UK.
[2]School of Education, University of Birmingham, UK

*Correspondence concerning the article should be addressed to Penny Hannant (penny.hannant@coventry.ac.uk), Centre for Innovative Research Across the Life Course, Coventry University, UK

Abstract

A number of studies have evidenced marked difficulties in language in autism spectrum conditions (ASC). Studies have also shown that language and word knowledge are associated with the same area of brain that is also responsible for visual perception in typically developing (TD) individuals. However, in ASC, research suggests word meaning is mapped differently, on to situational sensorimotor components within the brain. Furthermore, motor coordination is associated with communication skills. The current study explores whether motor coordination and visual perception are impaired in children with ASC, and whether difficulties in coordination and visual perception correlate with receptive language levels. 36 children took part: 18 with ASC and 18 TD children, matched on age and non-verbal reasoning. Both groups completed the Movement ABC, Beery-Buktenica Developmental Test of Visual-Motor Integration, British Picture Vocabulary Scale and Matrices (WASI). Results showed that ASC children scored significantly lower on receptive language, coordination and visual motor integration than the TD group. In the TD group receptive language significantly correlated with visual perception; in the ASC group receptive language significantly correlated with balance. These results imply that sensorimotor skills are associated with the understanding of language in ASC and thus the relationship between sensorimotor experiences and language warrants further investigation.

Keywords: Autism, sensorimotor, receptive language, visual perception, balance, embodied cognition, BA 37

Introduction

The ability to communicate effectively is a fundamental milestone in development and is critical to learning, socialising, behaviour and emotional well-being (Lindsay & Dockrell, 2010). However, children with an Autism Spectrum Condition (ASC) find it difficult to communicate and interact with others from infancy (Dawson, Osterling, Meltzoff & Kuhl, 2000). Consequently, current diagnostic criteria for ASC (DSM-5, APA, 2013) include social communication and interaction difficulties, in addition to unusual sensory responsivity and motor movements. (Current DSM-5 criteria (APA, 2013) refer to autism as a “disorder”, the current study uses the less stigmatising term “condition”; acknowledging both strengths and weaknesses in autism, while still being a medical condition for which individuals need support).

A number of studies have demonstrated impaired language in ASC, and although not a universal characteristic of ASC is well recognised, with some prevalence rates observed at 57% (Loucas, Charman, Pickles, Simonoff, Chandler, Meldrum & Baird, 2008), and 76% (Kjelgaard & Tager-Flusberg, 2001). Moreover, by using a number of standardised assessments to measure the quality of functional language in ASC children, such as the Clinical Evaluation of Language Fundamentals (CELF-3; Semel, Wiig & Secord, 1995), indistinguishable weaknesses in receptive and expressive language, and grammar have been demonstrated (Jarrold, Boucher & Russell, 1997; Kwok, Brown, Smyth & Cardy, 2015). Studies have also compared functional language ability in children with ASC to Speech and Language Impairment (SLI), demonstrating greater impairment in receptive language in ASC (Loucas et al. 2008). This finding was reiterated in a longitudinal study that showed children with a receptive language disorder are often difficult to distinguish from those with an ASC in terms of their language outcomes (Howlin, Mawhood & Rutter, 2000). Other studies that demonstrate differences in language include Dunn, Gomes and Gravel (2008), Dunn and Bates (2005), Bishop and Norbury (2002), Norbury (2005), Lloyd, Paintin and Botting (2006), Ungerer and Sigman (1987) and Luyster, Kadlec, Carter and Tager-Flusberg (2008). Moreover, language difficulties are considered a possible requisite to a diagnosis of ASC according to the current DSM-5 criteria (APA, 2013).

Difficulties in language have been shown to affect social communication skills in individuals with and without ASC. For example: when measuring social confidence, preschool children preferred playmates with similar linguistic skills (Brighi, Mazzanti, Guarini & Sansavini, 2015); using a longitudinal study on children from 2.5 years to 5.5 years of age, ASC children who had deficits in receptive and expressive language growth had persistently high trajectories using calibrated severity scores (Venker, Ray-Subramanian, Bolt & Weismer, 2014); and the social functioning in two groups of individuals, one with ASC and one with SLI, from initial studies at age 7-8 to a follow-up study at 23-24 years of age, had similar and significant difficulties in stereotyped behavioural patterns, social functioning, jobs and independence (Howlin et al., 2000). Therefore, identifying possible causes behind such language and communication difficulties in ASC would be an important advancement in understanding the symptoms.

Previous research has associated language and communication with sensorimotor skills. For example, the emergence of sitting skills has been linked to receptive language development (Libertus & Violi, 2016), fine motor skills in infants are related to expressive language development (LeBarton & Iverson, 2013) and impairments in motor abilities have been identified in SLI (Iverson & Braddock, 2011). More specifically, in ASC, early gross motor abilities have been found to predict language development (Bhat, Galloway & Landa, 2012; Bedford et al., 2016) and have also been associated with the development and severity of social skills in ASC (Green, Charman, Pickles, Chandler, Loucas, Simonoff, & Baird, 2009; Ming, Brimacombe, & Wagner, 2007; MacDonald, Lord, & Ulrich, 2013; Hannant, Cassidy, Tavassoli & Mann, 2016). This finding is further substantiated by research showing that deaf children with ASC also had receptive language skills that correlated with praxis performance (Bhat, Srinivasan, Woxholdt, & Shield, 2016). More specific observations demonstrate that significant impairments in motor skills also appear to result in limited gesture in ASC (Mostofsky, Dubey, Jerath, Jansiewicz, Goldberg & Denckla, 2006): in turn, this restricted gesture has been identified as a significant predictor of receptive language in pre-schoolers with ASC (Luyster et al., 2008). Difficulties with speech pronunciation due to oral motor difficulties could also impact on social acceptance and interaction in ASC (Page & Boucher, 1998; Gernsbacher, Sauer, Geye, Schweigert, & Hill Goldsmith, 2008). Moreover, children who have fine motor difficulties in early childhood (from 7 months old) are considered to be more at risk of developing an ASC by 3 years old (Landa & Garrett-Mayer, 2006).

Any link between the ability to coordinate movement and language impairment could be deemed unusual and disparate, however a theory that extraordinarily connects these two dimensions together is the ‘embodied cognition hypothesis’. This theory suggests conceptual information is represented within the sensorimotor systems (Mahon & Caramazza, 2008), where it is thought ‘cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities’ (Rosch, Thompson & Varela, 1992: p172-173). Such a theory can be observed in the ‘action-sentence compatibility effect’ (Borreggine & Kaschak, 2006), where sentence meaning interacts with movements made during oral sentence presentation. A further example is where olfactory anchors stimulate memory (Engen, 1991). Moreover, a systematic lag between the age of the earliest memory and the age of acquisition of the associate word has been observed (Morrison & Conway, 2010), which is thought to reflect the formation of the conceptual knowledge required from details in the episodic memories and situational contexts. This could also account for the relation between coordination and language in infants, such as the link between sitting and language (Libertus & Violi, 2016). Thus, there appears to be a rationale for a sensorimotor and language relation.

In addition to sensorimotor skills correlating with language, visual perception also appears to be directly associated with receptive language. Both receptive language acquisition and the visual representation of auditory linguistic information occur in the same area of the brain, area BA 37. This area of the brain is within the Wernicke’s area, which is thought to be linked to the semantic/lexical system (Ardila, 2011) and appears to not only have language but also visual perception functions (Ardila, Bernal & Rosselli, 2015; Milner & Goodale, 2008; Pammer, Hansen, Kringelbach, Holliday, Barnes, Hillebrand, Singh & Cornelissen, 2004; and Stewart, Meyer, Frith & Rothwell, 2001). Moreover, recent research has identified that the verbal labelling of objects augments visual input (Souza & Skóra, 2017), providing more evidence for coaction within this area. However, this association seems to differ in individuals with developmental disorders such as ASC and SLI. By analysing a number of imaging studies of BA 37 activation during sentence comprehension, Glezerman (2013) found that instead of mapping words on to the categorical and empirical components of the left hemisphere (LH), individuals with ASC and SLI would primarily match word meaning to the situational-experiential contexts of the right hemisphere (RH). Moreover, Glezeman (2013) suggests that only in ASC is word meaning mapped onto the situational sensorimotor level in the RH BA 37. Therefore, the Broca’s area may well be important in linking difficulties in visual perception and/or sensorimotor skills to receptive language difficulties.

Additionally, it is important to consider any link between visual feedback and motor control as visual information is essential to the planning and performing of motor movements (Brooks, 1983; Wolpert & Flanagan, 2001). For example, an individual needs to be responsive to where items are visually in order to grasp, reach or avoid them. Consequently, any perceptual or underlying cognitive difficulties in visual guidance are likely to affect the ability to acquire and modify a motor command for effective motor coordination. Adults with ASC have difficulty coordinating hand / eye movements (Glazebrook, Gonzalez, Hansen & Elliott, 2009). Additionally, by measuring both form and motion coherence in ASC, a link between visual motion responsivity and fine motor control has been observed (Milne, White, Campbell, Swettenham, Hansen & Ramus, 2006). Difficulties integrating visual cues from the environment with motor movements have also been demonstrated (Dowd, McGinley, Taffe & Rinehart, 2012). Furthermore, motor coordination deficits in children with a Developmental Coordination Disorder (DCD) were significantly related to their visual perceptual deficits (Cheng, Ju, Chang, Chen, Pei, Tseng & Cheng, 2014).

Research has found correlations between language, visual perception and coordination. Studies have also indicated disparity in word mapping within the BA 37 area of the brain: where TD individuals map word meaning on to the left hemisphere categorical visual components and ASC appear to map on to right hemisphere sensorimotor components. Furthermore, many interventions to support communication in ASC work on the basis of visual cues, such as the Pictorial Exchange System (PECs: Bondy & Frost, 1994). However presently there is limited research into the causes of receptive language difficulties in ASC. Exploring how and why receptive language in ASC differs to typically developing (TD) children may help guide intervention and assessment processes. Therefore, the current study explores whether: 1) there is a significant difference in receptive language ability, visual perception and motor coordination between children with and without ASC; and if 2) visual perception and motor coordination correlate with receptive language ability in children with and without ASC. The hypothesis is that receptive language will be impaired in children with ASC in comparison to TD controls, in addition to receptive language correlating with both visual perception and sensorimotor skills in TD children and sensorimotor skills alone in children with ASC.

Method

Participants

Two groups of children took part in a larger study exploring the impact of sensorimotor skills on social and communication skills: an ASC group and a TD group. The ASC group was recruited from local ASC support groups in Warwickshire, UK and was comprised of 18 children, (13 male, 5 female) aged 7-16 (mean age – 9.9 years). All children with ASC had a pre-existing diagnosis of ASC from a trained clinician according to DSM-IV criteria. ASC diagnosis was also confirmed using the Autism Diagnostic Observation Schedule General – 2nd Edition (ADOS-2) (Rutter, DiLavore, Risi, Gotham & Bishop, 2012) and the Autism Diagnostic Interview Revised (Rutter, Le Couteur, Lord & Faggioli, 2005), administered by a research reliable rater. The ASC group were considered as having a high functioning ASC. The TD group were recruited by advertising in the local media in Warwickshire, UK and was comprised of 18 children (7 male, 11 female), aged 6-12 (mean age = 9.2 years). The TD group had no known disabilities or diagnoses. All participants completed: a measure of receptive language IQ (BPVS-III; Dunn & Dunn, 2009); performance IQ (WASI matrices subset; Wechsler & Hsiao-pin, 2011); a measure of visual motor integration (Beery & Beery, 2010); a measure of motor coordination (Movement ABC; Henderson, Sugden & Barnett, 2007); and a parent report measure of autistic traits (Social Communication Questionnaire; SCQ; Rutter, Bailey & Lord, 2003). Participants were matched on age and performance IQ, but not gender (table 1). However, there was no effect of gender on receptive language, visual perception or motor coordination measures in either the ASC group (BPVS-III t(16)=1.25, *p*=.23; BEERY VP *t*(16)=1.17, *p*=.26; Movement ABC *t*(16)=.29, *p*=.78) or the TD group (BPVS-III t(16)=.00, *p*=1.00; BEERY VP *t*(16)=.47, *p*=.65; Movement ABC *t*(16)=.18, *p*=.86. No participants in the TD group scored above cut off indicating ASC on the SCQ (15). See Table 1 for characteristics of both groups. Note, a Bonferoni correction was not applied to the demographic statistics in order to ensure that any significance at a more conservatory level was reported.

Table 1: Demographic descriptives and group comparisons.

Group	Gender	Age in Years	Non-Verbal Reasoning
ASC (N=18)	13 M 5 F	9.93±2.71	90.94±13.28 (71-112)
TD (Control) (N=18)	7 M 11 F	9.16±1.89	99.50±12.68 (70-117)
Difference	$X^2(1,18)=4.05$, *p*=.044*	*t*(34)=-1.00, *p*=.325	*t*(34)=-1.98, *p*=.056

Materials

Participants completed a battery of four assessments that were standardised (MABC, BEERY, BPVS-III, WASI) where a standardised score of 115 or above was considered above average and 84 or below was considered below average. A further assessment (SCQ) was criterion based with a given cut-off point. Raw scores were used on the MABC only, in order to measure any correlation more accurately on each subset as standardised scores on the MABC are rounded up or down in fives i.e. 90-95-100, which does not support a detailed analysis of findings.

The Movement Assessment Battery for Children – 2 (Movement-ABC 2; Henderson, Sugden and Barnett 2007): A standardised assessment of motor coordination for children aged 3 - 16 years which is comprised of three components: manual dexterity, ball skills, static and dynamic balance. Examples of test content include placing pegs onto a board, throwing a beanbag onto a target and walking heel to toe along a line. The Movement-ABC 2 was normed on 1172 children aged 3-16 years with and without disabilities. Internal Reliability includes internal consistency estimates (range = .92-1.00) and criterion related validity with the 'Draw-a-Man' test = 0.66 (Kavazi, 2006). Test Duration: 20-40 minutes

The Beery-Buktenica Developmental Test of Visual-Motor Integration, Sixth Edition (BEERY VMI; Beery, Beery and Buktenica, 2010): A standardised measure of an individual's ability to combine visual perception and fine motor coordination for people aged 2-100 years which is comprised of three parts: visual motor integration, visual perception and fine motor coordination. The visual motor integration (VMI) assessment requires an individual to copy a series of developmentally progressive geometric shapes; the visual perception (VP) aspect involves identifying matching shapes; and the motor coordination subtest contains a variety of shape outlines that the individual draws lines within. The BEERY VMI (6th Ed) was normed on 1737 individuals aged 2-18 years with and without disabilities. Inter-rater reliability (range = .93-.98) and construct validity (range = .80-.95) have been demonstrated within the sixth edition (Beery & Beery, 2010). Test Duration: 10-15 minutes

The British Picture Vocabulary Scale III (BPVS-III; Dunn & Dunn, 2009): A standardised non-reading assessment of receptive language. Each item within the assessment consists of identifying the correct image out of four pictures provided, to match a given word that covers a range of subjects, such as verbs, animals, emotions, toys and attributes. The BPVS-III was normed on 3278 children aged 3-16 years with and without disabilities. Internal reliability = .91 and criterion validity with the Wechsler Intelligence Scale for Children (2005) = 0.76 (Dunn & Dunn, 2009). Test Duration: 10-15 minutes

The Social Communication Questionnaire - Lifetime (SCQ; Rutter et al, 2003): A standardised parent-report measure of autistic traits for children from 4 years of age. The lifetime form is composed of 40 yes or no questions and is used as a screening tool indicating whether referral for diagnosis of ASC is warranted. Scores of 15 or above out of 40 indicate a possible diagnosis of ASC. The SCQ was normed on 214 children aged 2-18 years with and without disabilities. Internal reliability = .84-.93 and construct validity with the ADI-R = 0.78 (Rutter et al., 2003) Test Duration: <10 minutes

Wechsler Abbreviated Scale of Intelligence – 2nd Edition (WASI-II; Wechsler & Hsiao-pin, 2011). A brief standardised measure of verbal and performance intelligence. The matrices subset was used in the current study to measure non-verbal reasoning in both groups. The WASI was normed on approximately 2900 individuals aged 6-90 years with and without disabilities. Matrix Internal Reliability = .87-.94 and construct validity with the WRIT = 0.71 (Wechsler & Hsiao-pin, 2011). Test Duration: <10 minutes

The following diagnostic measures were also completed by the ASC group to independently confirm participants ASC diagnosis and indicate severity of ASC symptoms:

Autism Diagnostic Observation Schedule – 2nd Edition (ADOS-II; Rutter, et al., 2012): A standardised diagnostic instrument for diagnosis of ASC, and confirmation of ASC diagnosis for research purposes. It consists of a semi-structured interview that provides a number of social presses and opportunities to code quality of social and communicative behaviours. The 2nd Edition of the ADOS also includes a rating indicating the severity of ASC symptoms taking into account the person’s age and expressive language level. The

ADOS-II was validated on 381 individuals aged between 15 months to 40 years with and without disabilities, with a further 1139 children aged between 14 months to 16 years recruited to revise the algorithms. Inter-rater reliability showed over 80% agreement on all modules with a high level of discriminative validity between autism and TD resulting in specificities of 50 to 84% and sensitivities of 91 to 98% (Rutter et al., 2012). Test Duration: ≈60 minutes

Autism Diagnostic Interview – Revised (ADI-R; Rutter, et al., 2005): A standardised diagnostic instrument for diagnosis of ASC, and confirmation of ASC diagnosis for research purposes. It consists of a detailed semi-structured interview to gather evidence from an informant (parent, sibling or partner of an individual) on an individual's current behaviour and early development indicative of an ASC diagnosis. Interviews cover social behaviour and communication, repetitive stereotyped behaviours, sensory and motor skills, talents, and challenging behaviours. The ADI-R was validated on 50 children aged between 36 to 59 months with and without disabilities. Internal Reliability of diagnositic classification was κCohen 0.83 (Zander, Willfors, Berggren, Coco, Holm, Jifält, Kosieradzki, Linder, Nordin, Olafsdottir and Bölte, 2017). The ADI-R also shows a high level of discriminative validity with Clinical Diagnosis with 24 out 25 children being correctly diagnosed using the ADI-R (Rutter et al., 2005) Test Duration: ≈180 minutes

Procedure

The local research ethics committee gave ethical approval for the study. Following parental consent to take part in the study, the parent completed the ADI-R either in person or over the phone with a researcher who was research reliable in both ADI-R and ADOS-II (ASC group only). Both child and parent then attended a single assessment session at the University. During this session, the following assessments were carried out in random order to counterbalance and combat order affects: BEERY VMI, Movement ABC, ADOS-II (on ASC group only), BPVS-III and WASI performance subsets; the participant's parent also completed the SCQ. Before the assessment procedure each task was explained carefully and depending on autism severity, a visual timetable produced to help alleviate anxiety. During the test procedure each participant was invited to have a voluntary break after each assessment. Additionally, each task was both demonstrated and practiced according to the manual instructions to ensure understanding.

Analysis approach

Data were analysed using SPSS (version 22), and normality tests conducted using Skewness and Kurtosis outputs. No deviations of normality were observed across all measured variables (z scores were all between -1.96 and +1.96). Following tests for normality, TD and ASC data were compared using Bonferroni corrected independent t-tests. A correlation analysis was then performed between the receptive language, coordination subtest scores and visual motor integration subset scores. Cohen's d was used as an indicator of effect size, with 0.2 indicating a small, 0.5 medium and 0.8 a large effect. These correlations were then followed up by a stepwise linear regression, using receptive language as the outcome measure, and age, Matrices, visual perception and balance scores as predictors. Post Hoc power analyses on the multiple regression model were conducted using G*Power 3 (Faul, Erdfelder, Lang & Buchner, 2007) to compute the achieved statistical power for each model.

Results

Do children with ASC show significant receptive language, visual perception and motor difficulties?

Table 2 shows results of comparisons between the ASC and TD groups on all measures. Bonferroni corrected independent samples *t*-tests showed that children with ASC had significantly lower receptive language ability, motor coordination skills, visual motor integration, visual perception and higher parent reported autistic traits than the TD group, all with large effect sizes according to Cohen's *d*. With Bonferroni correction the difference in balance and visual motor integration was not considered significant (p=.016; p=.009 respectively); however the effect size of the difference between groups in these subsets is still noteworthy.

Table 2: Dependent variable descriptives and comparison of means, where the BPVS-III is a measure of receptive language, MABC is a measure of coordination, SCQ a measure of social awareness and the BEERY, a measure of visual motor integration and perception.

Group	BPVS-III Standardised Score	MABC Composite Total	MABC Balance	MABC Manual Dexterity	SCQ score	BEERY VMI (ASC N=17)	BEERY VP
ASC (N=18)	88.56± 14.08 70-119	51.61±15.69 25-71	22.67±8.17 8-33	16.56±8.60 5-32	18.94±7.94 8-35	84.24±21.27 48-120	92.94±14.85 69-130
Control (N=18)	106.00±12.02 77-127	74.28±14.12 46-92	28.89±6.49 17-36	29.94±5.51 14-38	3.83±3.68 0-13	100.17±8.93 82-116	110.06±7.60 95-125
Difference	*t*(34)=-4.00, *p*=.000*, ***d*=-1.33**	*t*(34)=-4.56, *p*=.000*, ***d*=-1.52**	*t*(34)=-2.53, *p*=.016, ***d*=-.84**	*t*(29)=-5.56, *p*=.000*, ***d*=-1.85**	*t*(24)=7.33, *p*=.000*, ***d*=2.44**	*t*(21)=-2.86, *p*=.009, ***d*=-.98**	*t*(25)=-4.35, *p*=.000*, ***d*=-1.45**

Note: Effect size Cohen's d: 0.2 = small, 0.5 = medium, 0.8 = large.

** Significant results after bonferroni corrected p value = .007*

Do visual perception and motor coordination correlate with receptive language ability?

In both the ASC and TD group, separate and joint correlation analyses were conducted between receptive language and the coordination total, balance and manual dexterity composites, and the visual perception and visual motor integration composites. Non-verbal reasoning skills were also included in order to determine any similarities in correlations with receptive language, as both operationalisations (BPVS-III and Matrices) rely on visual processing to access the test.

Table 3 shows results of the correlations. In the ASC group the balance subset significantly correlated with receptive language (*r* = .57, *p* = .007). In the TD group the visual perception subset significantly correlated with receptive language (*r* = .57, *p* = .007). Non-verbal reasoning significantly correlated with receptive language in the TD alone (*r* = .66, *p* = .002), with no significant relation in the ASC group (*r* = .30, *p* = .116). When the ASC and TD groups were combined all variables, visual motor integration (*r* = .54, *p* < 001), visual perception (*r* = .56, *p* < 001), coordination total (*r* = .60, *p* < 001), balance (*r* = .59, *p* < 001), manual dexterity (*r* = .60, *p* < 001) and non-verbal reasoning (*r* = .54, *p* < 001) significantly correlated with receptive language. Figure 1 demonstrates visually how visual perception and balance correlated with receptive language between groups.

Table 3: Correlation analyses (*R)* for all measures across ASC, TD and Total group, where the BPVS-III is a measure of receptive language, MABC is a measure of coordination, the BEERY, a measure of visual motor integration and perception, and WASI Matrices a measure of non-verbal reasoning.

		BEERY VMI	BEERY VP	MABC Manual Dexterity	MABC Balance	MABC TOTAL	WASI MATRICES
BEERY VP	ASC (18)	**.797*****					
	TD (18)	.134					
	TOTAL (36)	**.745*****					
MABC Manual Dexterity	ASC (18)	**.536***	.410*				
	TD (18)	-.223	-.150				
	TOTAL (36)	**.541*****	**.570*****				
MABC Balance	ASC (18)	**.554***	**.556****	**.663****			
	TD (18)	.101	.093	**.580****			
	TOTAL (36)	**.513****	**.542*****	**.694*****			
MABC TOTAL	ASC (18)	**.611****	.497*	**.924*****	**.840*****		
	TD (18)	.043	-.084	**.781*****	**.908*****		
	TOTAL (36)	**.572*****	**.560*****	**.915*****	**.872*****		
WASI MATRICES	ASC (18)	**.600****	.517*	.465*	.446*	.495*	
	TD (18)	.407*	.307	.316	.444*	.353	
	TOTAL (36)	**.568*****	.518**	.496**	.513**	.518**	
BPVS-III	ASC (18)	.379	.257	.399	**.573****	.464*	.297
	TD (18)	.493*	**.567****	.272	.345	.299	**.656****
	TOTAL (36)	**.542*****	**.564*****	**.600*****	**.588*****	**.603*****	**.539*****

*Note: * p <0.05, ** p < 0.01, *** p < 0.001. Required Effect Size = .522 (Power = .80, α = 0.05, 18 Sample Size)*
Correlations in ***bold*** *indicate results > required effect size*

Does visual perception correlate with balance?

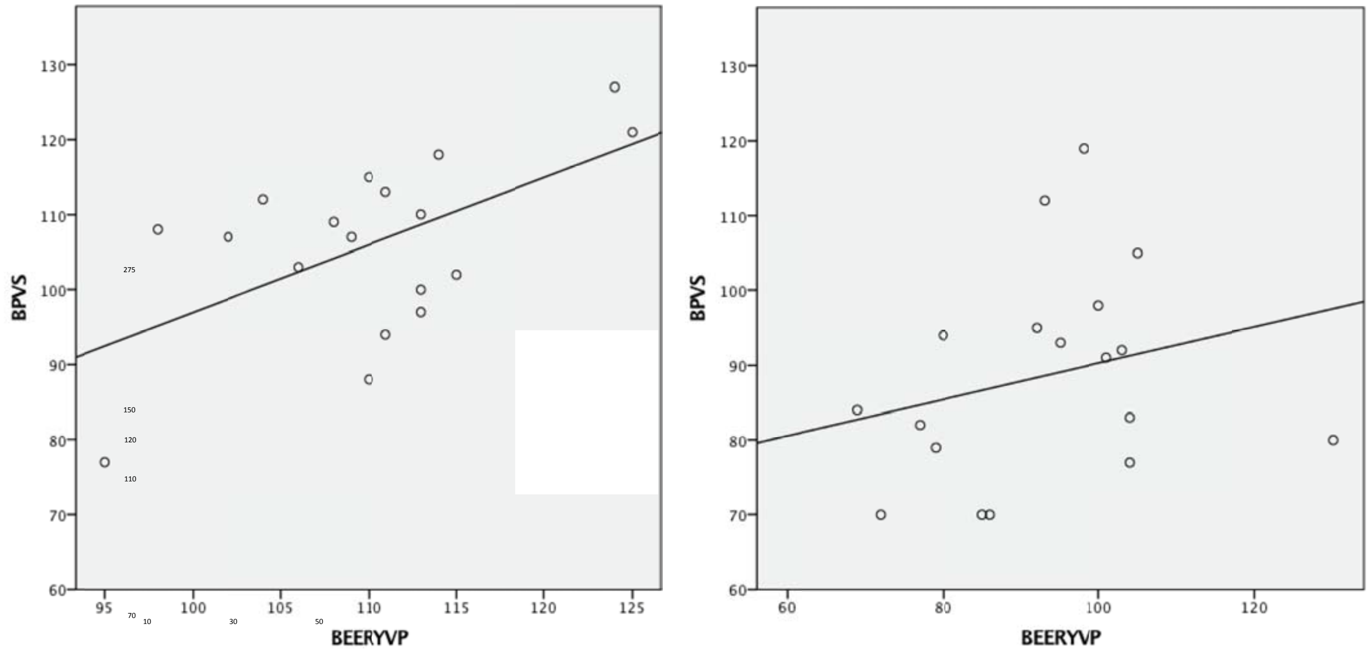
The correlational analysis demonstrated that visual perception significantly correlated with balance in the ASC group alone (*r* = .56, *p* = .008). There was no significant correlation between balance and visual perception in the TD group (*r* = .09, *p* = .356).

Figure 1: Scatterplots to show correlations with receptive language (BPVS-III) in the ASC and TD groups

Key: BPVS-II: British Picture Vocabulary Scale III; MABCBCOMP: Movement Assessment Battery for Children Balance;

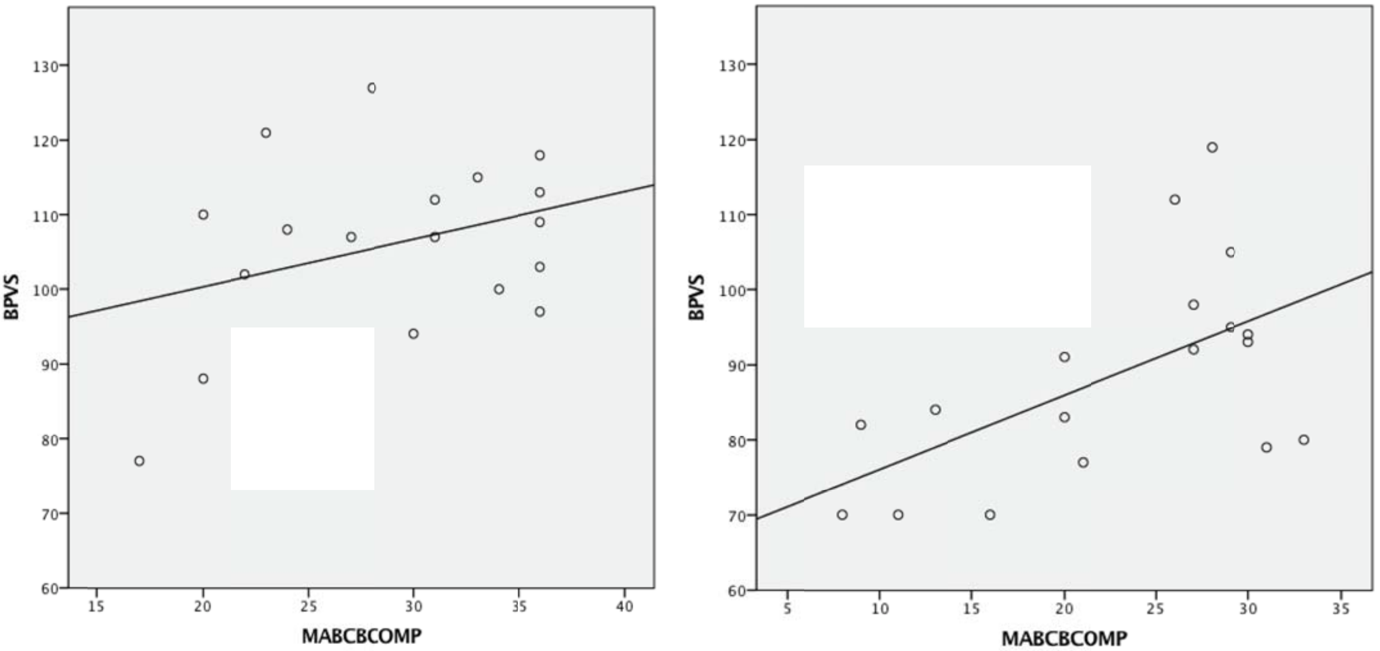
Receptive language correlation with visual perception (TD Group)

Receptive language correlation with visual perception (ASC Group)



Receptive language correlation with balance (TD Group)

Receptive language correlation with balance (ASC Group)



BEERYVP: Visual Perception

Table 4 shows results of the stepwise regressions in order to control for any extraneous variables. In the TD both non-verbal reasoning and visual perception were retained as significant predictors of receptive language. In the ASC group the balance subset alone was retained as a significant predictor of receptive language. These predictors were retained when both age and performance IQ were included. In summary, these results showed that the visual perception scores significantly predicted TD receptive language and the balance measures significantly predicted receptive language in ASC when accounting for age and performance IQ. Non-verbal reasoning (Matrices) predicted some, but not all, of the receptive language in TD individuals.

Table 4: Stepwise multiple regressions for receptive language in the TD and ASC group.

Step	Variable	*B*	*SE B*	Β	Cum R^2
		Typically Developing Group (n=18)			
1	Constant	44.11	17.93		
	MATRICES	.62	.18	.66**	.66
2	Constant	-14.54	30.15		
	MATRICES	.50	.17	.53**	.76
	BEERYVP	.64	.28	.40*	
		ASC Group (n=18)			
1	Constant	66.18	8.49		
	MABC BALANCE	.99	.35	.57**	.57

*Note: * p <0.05, ** p < 0.01, *** p < 0.001.*

Typically Developing Model 2 achieved 0.6 Statistical Power for a sample size of 18

Autism Spectrum Conditions Model 1 achieved >0.8 Statistical Power for a sample size of 18

Key: Matrices measures non-verbal language; BEERYVP measures visual perception and MABC Balance measures balance

Discussion

Do children with ASC show significant receptive language, visual perception and motor difficulties?

The current study investigated whether children with ASC show significant difficulties in receptive language, visual perception and motor coordination when compared to TD children and whether visual perception and motor coordination are associated with receptive language. Results agreed with our first hypothesis and demonstrated that children with ASC had significant receptive language, visual perception and motor coordination difficulties when compared to age and performance IQ matched children without ASC. These results confirm findings with regards to impaired language by Dunn et al. (2008) and coordination by MacDonald et al. (2013) and add to findings with regards to visual perception in ASC, by suggesting visual perception is a comparable area of weakness in ASC.

Do visual perception and motor coordination correlate with receptive language ability?

When considering whether visual perception and motor coordination are associated with receptive language ability, the results partially agreed with our hypothesis, that receptive language in TD children would correlate with both visual perception and sensorimotor skills, whist in ASC receptive language would correlate with sensorimotor skills alone. However, there were distinct differences between children with and without ASC. In TD children, visual perception was shown to significantly correlate with receptive language with a medium to large effect size, whilst sensorimotor skills showed no significant correlation. However, in the ASC group visual perception was not associated with receptive language: instead balance significantly correlated with receptive language with a medium to large effect size. Furthermore, data analysis showed a correlation between visual perception and balance in the ASC group alone with a medium effect size. Studies have shown a similar link between visual perception and balance in both SLI (Nicola, Watter, Dalton & Tracy, 2015) and DCD (Cheng et al., 2014), with the same discrepancy echoed: no link between visual perception and motor skills in the TD children. The following discusses possible reasons based on the results of this study as to why receptive language may be impaired in ASC.

Visual processing differences in ASC may lead to language difficulties

Differences in the processing of receptive language in ASC could be associated with visual processing difficulties and a consequential over-reliance on the other senses, thus processes that rely heavily on visual representation, such as language, may also be affected. Evidence for this can be seen in research conveying that children with ASC rely more heavily on proprioceptive feedback than on visual feedback for the correction of movement (Marko, Crocetti, Hulst, Donchin, Shadmehr, & Mostofsky, 2015; Izawa, Pekny, Marko, Haswell, Shadmehr & Mostofsky, 2012; Schmitz, Martineau, Barthélémy & Assaiante, 2003; Gepner & Mestre, 2002). Additionally, studies have identified deficits in ASC when compared to controls in areas of visual processing such as visual attention (Ronconi, Gori, Ruffino, Molteni & Facoetti, 2013), accuracy when moving eyes from a central fixation point to a peripheral target (Schmitt, Cook, Sweeney & Mosconi, 2014; Mosconi, Luna, Kay-Stacey, Nowinski, Rubin, Scudder, Minshew & Sweeney, 2013) and delay in initiating a saccade when following a moving light (Wilkes, Carson, Patel, Lewis & White, 2015).

Differences in processing semantic information in ASC may lead to language difficulties

Differences in how semantic information is processed in ASC is also noteworthy. For example, children with ASC differed from TD children by not utilising semantic priming when asked to name near-semantically related words, such as truck-car (Kamio, Robins, Kelley, Swainson & Fein, 2007). Moreover, by referring to a number of studies that include functional neuroimaging, unilateral brain damage and impairment of conceptual understanding in ASC, the aforementioned review by Glezerman (2013) presents the difference in word comprehension as being created by ‘reversed lateralization’, where individuals with ASC map word meaning onto the situational ‘sensorimotor’ components of the right hemisphere of the BA 37, as opposed to the categorical and empirical components of the left hemisphere (See Glezeman, 2012 for a more detailed account). In addition to this a further review of Positron Emission Tomography (PET) studies demonstrated abnormal patterns of cortical activation in ASC, providing further evidence of inefficient language processing in the left hemisphere (Rodríguez-Rojas, Machado, Batista, Carballo, & Leisman, 2015). The mapping of language and associations of language with sensorimotor experiences would also help to explain some learning difficulties in ASC, such as hyperlexia (superior word-reading skills in comparison to comprehension, (Newman, Macomber, Naples, Babitz, Volkmar & Grigorenko, 2007) and real-life difficulties faced by individuals with ASC on a daily basis, such as non-verbal communication issues, as both rely heavily on the visual representation of meaning rather than experience.

The Embodied Cognition could lead to language difficulties in ASC

The visual processing difficulties and over-reliance on body position in ASC could also accentuate the aforementioned ‘embodied cognition hypothesis’ (the representation of conceptual information within the sensorimotor system, Mahon & Caramazza, 2008), thus impacting on the empirical and visual acquisition of language. For example, in such a theory, language is essentially learnt from sensorimotor experiences as well as labelling visual representations of objects. With difficulties in the latter, children with ASC may develop language based on their sensorimotor experiences alone, which as noted in the APA DSM-5 criteria (APA, 2013), are often also impacted.

Limitation of the Study

It was difficult to decide on background variables to match the ASC and control group. Matching controls with language and verbal IQ was not appropriate as we were examining the unusual language profile in ASC. Similarly, we did not want to use a non-verbal IQ test that relied heavily on visuo-spatial skills. For this reason, the matrices subset of the performance IQ was chosen as a non-verbal IQ match. However, it is important to note that the matrices assessment is similar to the BPVS-III in that the participant has to select one of a set of visual representations as the answer. Additionally, in the TD children the BPVS-III correlated with the matrices score ($r = .66$, $p = .002$), consequently this measurement was also not entirely suitable. Thus, participants were matched firstly on age and then on matrices performance. This finding would also suggest that the BPVS-III is not a suitable assessment to measure performance in children with ASC.

A limitation of the current study is that it includes a reasonably small sample (18) in each group. However, Bonferroni correction was utilised and analysis was shown to have medium to large effect sizes, hence there was sufficient statistical power for the analysis. Furthermore, the study gathered a rich dataset consisting of a number of high quality standardised measures and independent confirmation of ASC diagnosis, which may not have been possible for a larger sample size. Another limitation is the cross-sectional nature of the data collection, which does not allow for causal interpretations. Finally, the difference in nonverbal IQ between the groups approached significance (without Bonferoni correction), though it was clearly smaller in effect size than the differences found in language and visual perception.

In conclusion, this study indicates that receptive language in ASC is correlated with sensorimotor skills as opposed to visual perception, as seen in TD. This finding, in addition to previous research with regards to ‘embodied cognition’ and differences in semantic mapping, suggests that the receptive language difficulties that children with ASC experience could be related to their sensorimotor experiences. Accordingly, the findings from this study could impact on present interventions that rely heavily on visual imagery to develop language in ASC, such as picture exchange systems and pictorial representations of emotion and therefore warrants further investigation. If language is associated with sensorimotor abilities and experiences rather than visual representation in ASC, language programmes and assessments may benefit from including such pedagogy in the form of objects, sensory experiences, life experiences and photographs in addition to sensorimotor integration programmes. Moreover, clinicians and educators should be aware that interventions which support the motor impairments and balance of children with ASC at an early age, are also of great importance and benefit. A possible area for future investigation would be to explore whether the substitution of pictorially represented images with real-life images in language assessments alter outcomes of receptive language assessments favourably.

Acknowledgements.
This work was funded by the Centre for Innovative Research Across the Life Course, Coventry University, UK.
With thanks to:
Local Support groups and Parents

References

1. Ardila, A. (2011). There are two different language systems in the brain. *Journal of Behavioral and Brain Science*, *1*(02), 23.

2. Ardila, A., Bernal, B., & Rosselli, M. (2015). Language and visual perception associations: Meta-analytic connectivity modeling of Brodmann area 37. *Behavioural neurology*, *2015*.

3. American Psychiatric Association. (2013). *Diagnostic and] statistical manual of mental disorders* (5th ed.). Washington, DC: Author

4. Beery, K. E., & Beery, N. A. (2010). *The Beery-Buktenica developmental test of visual-motor integration (Beery VMI) with supplemental developmental tests of visual perception and motor coordination and stepping stones age norms: Administration, scoring and teaching manual*. Minneapolis, MN: NCS Pearson.

5. Bhat, A. N., Galloway, J. C., & Landa, R. J. (2012). Relation between early motor delay and later communication delay in infants at risk for autism. *Infant Behavior and Development*, *35*(4), 838-846.

6. Bhat, A. N., Srinivasan, S. M., Woxholdt, C., & Shield, A. (2016). Differences in praxis performance and receptive language during fingerspelling between deaf children with and without autism spectrum disorder. *Autism*, 1362361316672179

7. Bishop, D. V., & Norbury, C. F. (2002). Exploring the borderlands of autistic disorder and specific language impairment: a study using standardised diagnostic instruments. *Journal of Child Psychology and Psychiatry*, *43*(7), 917-929.

8. Bondy, A. S., & Frost, L. A. (1994). The picture exchange communication system. *Focus on autistic behavior*, *9*(3), 1-19.

9. Borreggine, K. L., & Kaschak, M. P. (2006). The action–sentence compatibility effect: It's all in the timing. *Cognitive Science*, *30*(6), 1097-1112.

10. Brighi, A., Mazzanti, C., Guarini, A., & Sansavini, A. (2015). Young Children's cliques: a study on processes of peer acceptance and cliques aggregation. *International Journal of Emotional Education*, *7*(1), 69.

11. Brooks, V. B. (1983). Motor Control How Posture and Movements are Governed. *Physical Therapy*, *63*(5), 664-673.

12. Cheng, C. H., Ju, Y. Y., Chang, H. W., Chen, C. L., Pei, Y. C., Tseng, K. C., & Cheng, H. Y. K. (2014). Motor impairments screened by the Movement Assessment Battery for Children-2 are related to the visual-perceptual deficits in children with Developmental Coordination Disorder. *Research in developmental disabilities*, *35*(9), 2172-2179.

13. Dawson, G., Osterling, J., Meltzoff, A. N., & Kuhl, P. (2000). Case study of the development of an infant with autism from birth to two years of age. *Journal of Applied Developmental Psychology*, *21*(3), 299-313.

14. Dowd, A. M., McGinley, J. L., Taffe, J. R., & Rinehart, N. J. (2012). Do planning and visual integration difficulties underpin motor dysfunction in autism? A kinematic study of young children with autism. *Journal of autism and developmental disorders*, *42*(8), 1539-1548.

15. Dunn, M. A., & Bates, J. C. (2005). Developmental change in neutral processing of words by children with autism. *Journal of autism and developmental disorders*, *35*(3), 361-376.

16. Dunn, L. M., & Dunn, D. M. (2009). *The British picture vocabulary scale*. GL Assessment Limited.

17. Dunn, M. A., Gomes, H., & Gravel, J. (2008). Mismatch negativity in children with autism and typical development. *Journal of autism and developmental disorders*, *38*(1), 52-71.

18. Engen, T. (1991). *Odor sensation and memory*. Greenwood Publishing Group.

19. Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, *39*(2), 175-191.

20. Gepner, B., & Mestre, D. R. (2002). Brief report: postural reactivity to fast visual motion differentiates autistic from children with Asperger syndrome. *Journal of Autism and Developmental disorders*, *32*(3), 231-238.

21. Gernsbacher, M. A., Sauer, E. A., Geye, H. M., Schweigert, E. K., & Hill Goldsmith, H. (2008). Infant and toddler oral-and manual-motor skills predict later speech fluency in autism. *Journal of Child Psychology and Psychiatry*, *49*(1), 43-50.

22. Glazebrook, C., Gonzalez, D., Hansen, S., & Elliott, D. (2009). The role of vision for online control of manual aiming movements in persons with autism spectrum disorders. *Autism*, *13*(4), 411-433.

23. Glezerman, T. B. (2013). How Autistic Persons Understand Words (Cerebral Organization of Word Meaning and Autism). In *Autism and the Brain* (pp. 21-46). Springer New York.

24. Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., & Baird, G. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine & Child Neurology*, *51*(4), 311-316

25. Hannant, P., Cassidy, S., Tavassoli, T., & Mann, F. (2016). Sensorimotor Difficulties Are Associated with the Severity of Autism Spectrum Conditions. *Frontiers in Integrative Neuroscience*, *10*.

26. Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). *Movement assessment battery for children-2: Movement ABC-2: Examiner's manual*. Pearson.

27. Howlin, P., Mawhood, L., & Rutter, M. (2000). Autism and developmental receptive language disorder—A follow-up comparison in early adult life. II: Social, behavioural, and psychiatric outcomes. *Journal of Child Psychology and Psychiatry*, *41*(05), 561-578.

28. Iverson, J. M., & Braddock, B. A. (2011). Gesture and motor skill in relation to language in children with language impairment. *Journal of Speech, Language, and Hearing Research*, *54*(1), 72-86.

29. Izawa, J., Pekny, S. E., Marko, M. K., Haswell, C. C., Shadmehr, R., & Mostofsky, S. H. (2012). Motor Learning Relies on Integrated Sensory Inputs in ADHD, but Over-Selectively on Proprioception in Autism Spectrum Conditions. *Autism Research*, *5*(2), 124-136.

30. Jarrold, C., Boucher, J., & Russell, J. (1997). Language profiles in children with autism. *Autism*, *1*(1), 57-76.

31. Kamio, Y., Robins, D., Kelley, E., Swainson, B., & Fein, D. (2007). Atypical lexical/semantic processing in high-functioning autism spectrum disorders without early language delay. *Journal of Autism and Developmental Disorders*, *37*(6), 1116-1122.

32. Kavazi E. (2006) Motor competence in young Cypriot children. AN examination of cross-cultural differences and the value of human figure drawings in motor assessment. Oxford Brookes University: Unpublished Master’s thesis.

33. Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and cognitive processes*, *16*(2-3), 287-308.

34. Kwok, E. Y., Brown, H. M., Smyth, R. E., & Cardy, J. O. (2015). Meta-analysis of receptive and expressive language skills in autism spectrum disorder. *Research in Autism Spectrum Disorders*, *9*, 202-222.

35. Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry*, *47*(6), 629-638.

36. LeBarton, E. S., & Iverson, J. M. (2013). Fine motor skill predicts expressive language in infant siblings of children with autism. *Developmental science*, *16*(6), 815-827.

37. Libertus, K., & Violi, D. A. (2016). Sit to Talk: Relation between Motor Skills and Language Development in Infancy. *Frontiers in psychology*, *7*.

38. Lindsay, G., & Dockrell, J. E. (2012). The relationship between speech, language and communication needs and behavioural, emotional and social difficulties.

39. Lloyd, H., Paintin, K., & Botting, N. (2006). Performance of children with different types of communication impairment on the Clinical Evaluation of Language Fundamentals (CELF). *Child Language Teaching and Therapy*, *22*(1), 47-67.

40. Loucas, T., Charman, T., Pickles, A., Simonoff, E., Chandler, S., Meldrum, D., & Baird, G. (2008). Autistic symptomatology and language ability in autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry*, *49*(11), 1184-1192.

41. Luyster, R. J., Kadlec, M. B., Carter, A., & Tager-Flusberg, H. (2008). Language assessment and development in toddlers with autism spectrum disorders. *Journal of autism and developmental disorders*, *38*(8), 1426-1438.

42. MacDonald, M., Lord, C., & Ulrich, D. (2013). The relationship of motor skills and adaptive behavior skills in young children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *7*(11), 1383-1390.

43. Mahon, B. Z., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of physiology-Paris*, *102*(1), 59-70.

44. Marko, M. K., Crocetti, D., Hulst, T., Donchin, O., Shadmehr, R., & Mostofsky, S. H. (2015). Behavioural and neural basis of anomalous motor learning in children with autism. *Brain*, awu394.

45. Milne, E., White, S., Campbell, R., Swettenham, J., Hansen, P., & Ramus, F. (2006). Motion and form coherence detection in autistic spectrum disorder: Relationship to motor control and 2: 4 digit ratio. *Journal of autism and developmental disorders*, *36*(2), 225-237.

46. Milner, A. D. and Goodale, M. A., (2008) Two visual systems re-viewed. *Neuropsychologial, 46(3),* 774–785. View at Publisher · View at Google Scholar · View at PubMed · View at Scopus

47. Ming, X., Brimacombe, M., & Wagner, G. C. (2007). Prevalence of motor impairment in autism spectrum disorders. Brain and Development , 29 (9), 565-570.Renfrew, J (1972/1988) Action Picture Test. C. Renfrew 2A North Place, Oxford

48. Morrison, C. M., & Conway, M. A. (2010). First words and first memories. *Cognition*, *116*(1), 23-32.

49. Mosconi, M. W., Luna, B., Kay-Stacey, M. Nowinski, C. V., Rubin, L. H., Scudder, C., Minshew, N. & Sweeney, J. A, (2013). Saccade adaptation abnormalities implicate dysfunction of cerebellar-dependent learning mechanisms in Autism Spectrum Disorders (ASD). *PloS one*, *8*(5), e63709.

50. Mostofsky, S. H., Dubey, P., Jerath, V. K., Jansiewicz, E. M., Goldberg, M. C., & Denckla, M. B. (2006). Developmental dyspraxia is not limited to imitation in children with autism spectrum disorders. *Journal of the International Neuropsychological Society*, *12*(03), 314-326.

51. Newman, T. M., Macomber, D., Naples, A. J., Babitz, T., Volkmar, F., & Grigorenko, E. L. (2007). Hyperlexia in children with autism spectrum disorders. *Journal of autism and developmental disorders*, *37*(4), 760-774.

52. Nicola, K., Watter, P., Dalton, D., & Tracy G., (2015). The relationship between visual perceptual skills and motor performance in children with sever specific language impairment. www.physiotherapy.asn.au/Conference2015

53. Norbury, C. F. (2005). Barking up the wrong tree? Lexical ambiguity resolution in children with language impairments and autistic spectrum disorders. *Journal of experimental child psychology*, *90*(2), 142-171.

54. Page, J., & Boucher, J. (1998). Motor impairments in children with autistic disorder. *Child Language Teaching and Therapy*, *14*(3), 233-259.

55. Pammer, K., Hansen, P. C., Kringelbach, M. L., Holliday, I., Barnes, G., Hillebrand, A., ... & Cornelissen, P. L. (2004). Visual word recognition: the first half second. *Neuroimage*, *22*(4), 1819-1825.

56. Rodríguez-Rojas, R., Machado, C., Batista, K., Carballo, M., & Leisman, G. (2015). Neuroimages in autism. In *Translational Approaches to Autism Spectrum Disorder* (pp. 95-117). Springer International Publishing.

57. Ronconi, L., Gori, S., Ruffino, M., Molteni, M., & Facoetti, A. (2013). Zoom-out attentional impairment in children with autism spectrum disorder. *cortex*, *49*(4), 1025-1033.

58. Rosch, E., Thompson, E. & Varela, F. J. (1991). *The embodied mind: Cognitive science and human experience* (Paperback 1992 ed.). MIT Press. *ISBN* *978-0262720212*.

59. Rutter, M., Bailey, A., & Lord, C. (2003). *The social communication questionnaire: Manual*. Western Psychological Services.

60. Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule: ADOS-2*. Los Angeles, CA: Western Psychological Services.

61. Rutter, M., Le Couteur, A., Lord, C., & Faggioli, R. (2005). *ADI-R: Autism diagnostic interview--revised: Manual*. OS, Organizzazioni speciali.

62. Schmitt, L. M., Cook, E. H., Sweeney, J. A., & Mosconi, M. W. (2014). Saccadic eye movement abnormalities in autism spectrum disorder indicate dysfunctions in cerebellum and brainstem. *Molecular autism*, *5*(1), 47.

63. Schmitz, C., Martineau, J., Barthélémy, C., & Assaiante, C. (2003). Motor control and children with autism: deficit of anticipatory function?. *Neuroscience letters*, *348*(1), 17-20.

64. Semel, E. M., Wiig, E. H., & Secord, W. (1995). *CELF3: clinical evaluation of language fundamentals*. Psychological Corporation, Harcourt Brace.

65. Souza, A. S., & Skóra, Z. (2017). The interplay of language and visual perception in working memory. *Cognition*, *166*, 277-297.

66. Stewart, L., Meyer, B. U., Frith, U., & Rothwell, J. (2001). Left posterior BA37 is involved in object recognition: a TMS study. *Neuropsychologia*, *39*(1), 1-6.

67. Ungerer, J. A., & Sigman, M. (1987). Categorization skills and receptive language development in autistic children. *Journal of Autism and Developmental Disorders*, *17*(1), 3-16.

68. Venker, C. E., Ray-Subramanian, C. E., Bolt, D. M., & Weismer, S. E. (2014). Trajectories of autism severity in early childhood. *Journal of autism and developmental disorders*, *44*(3), 546-563.

69. Wechsler, D., & Hsiao-pin, C. (2011). *WASI-II: Wechsler abbreviated scale of intelligence*. Pearson.

70. Wilkes, B. J., Carson, T. B., Patel, K. P., Lewis, M. H., & White, K. D. (2015). Oculomotor performance in children with high-functioning Autism Spectrum Disorders. *Research in developmental disabilities*, *38*, 338-344.

71. Wolpert, D. M., & Flanagan, J. R. (2001). Motor prediction. *Current Biology*, *11*(18), R729-R732.

72. Zander, E., Willfors, C., Berggren, S., Coco, C., Holm, A., Jifält, I., ... & Bölte, S. (2017). The Interrater Reliability of the Autism Diagnostic Interview-Revised (ADI-R) in Clinical Settings. *Psychopathology*, *50*(3), 219-227.