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Do reciprocal associations exist between social and language pathways in preschoolers with autism spectrum disorders?

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Background: Differences in how developmental pathways interact dynamically in children with autism spectrum disorder (ASD) likely contribute in important ways to phenotypic heterogeneity. This study aimed to model longitudinal reciprocal associations between social competence (SOC) and language (LANG) pathways in young children with ASD. **Methods:** Data were obtained from 365 participants aged 2–4 years who had recently been diagnosed with an ASD and who were followed over three time points: baseline (time of diagnosis), 6- and 12 months later. Using structural equation modeling, a cross-lagged reciprocal effects model was developed that incorporated auto-regressive (stability) paths for SOC (using the Socialization subscale of the Vineland Adaptive Behavior Scales-2) and LANG (using the Preschool Language Scale-4 Auditory Comprehension subscale). Cross-domain associations included within-time correlations and lagged associations. **Results:** SOC and LANG were highly stable over 12 months. Small reciprocal cross-lagged associations were found across most time points and within-time correlations decreased over time. There were no differences in strength of cross-lagged associations between SOC-LANG and LANG-SOC across time points. Few differences were found between subgroups of children with ASD with and without cognitive impairment. **Conclusions:** Longitudinal reciprocal cross-domain associations between social competence and language were small in this sample of young children with ASD. Instead, a pattern emerged to suggest that the two domains were strongly associated around time of diagnosis in preschoolers with ASD, and then appeared to become more independent over the ensuing 12 months. **Keywords:** Autism spectrum disorder, social development, language, epidemiology, reciprocal effects model.

Introduction

Children with autism spectrum disorder (ASD) demonstrate significant impairment or differences in social reciprocity and communication abilities as well as repetitive, restricted or stereotyped behavior. However, there is substantial heterogeneity of symptoms, related impairment and functioning across individuals with such diagnoses. ASD may therefore be best understood as a disorders with multiple phenotypes. To link common early impairment or differences (e.g., at the level of genes or brain structure and function) to later variability across a range of autistic symptoms, comorbidity and daily functioning, we need to better understand the complex developmental processes that occur in between (Dawson et al., 2002; Karmiloff-Smith, 1998; Mundy, Henderson, Inge, & Coman, 2007; Tager-Flusberg, 2010).

Early social and language developmental pathways, and the interactions between these, are important candidate processes linking early impairment or differences and later heterogeneity of phenotypes in individuals with ASD. The achievement of fluent language (or lack of language impairment) and typical intellectual ability by age of 5–6 years has perhaps been most consistently related to better outcomes across multiple studies (Bennett et al., 2008; Howlin, Goode, Hutton, & Rutter, 2004; Rutter, Greenfeld, & Lockyer, 1967; Szatmari et al., 2009). A recent prospective longitudinal study has also found that childhood social reciprocity was strongly related to a composite of adult outcomes (including employment, relationships and independent living; Howlin, Moss, Savage & Rutter, 2013).

Several theories of language development among neurotypically developing (NTD) children emphasize the interrelatedness of language ability with emerging social competence – the degree to which a child demonstrates age-appropriate levels of social interest, social-cognitive skills and effective prosocial behavior. In particular, social learning theories of language development emphasize that social factors

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upstream in child development (i.e., during infancy and toddlerhood) are e.g. Bruner 1985; Tomasello and Farrar (1986) essential to subsequent language development (Bruner, 1985). Longitudinal empirical studies have underscored the importance of emerging social-developmental milestones such as gaze-following, joint attention, imitation, and the detection of others' intentionality for developing structural language skills (e.g., vocabulary, grammar; Mundy & Jarrold, 2010; Siller & Sigman, 2008). Experimental research demonstrated that social interaction (i.e., compared to video-recorded or computer-generated stimuli) needs to occur in order to optimize learning in infants in their first year, perhaps because of greater infant attentiveness to social stimuli or more enriched information provided by face-to-face teaching (Kuhl, 2010; Siller & Sigman, 2008). Much empirical evidence therefore converges on the theory that speech and language learning is 'gated by the social brain' (Kuhl, 2010).

An understanding of the social brain and social interactions as 'gating' child language development both informs, and is informed by, longitudinal studies of children with ASD. According to several developmental theories of ASD, critical levels of impairment in emerging social competence (e.g., orienting to faces, engagement in joint attention, imitation) likely play an important role in the underlying pathophysiology of ASD (Charman, 2003; Dawson et al., 2002; Mundy, Sullivan, & Mastergeorge, 2009; Mundy et al., 2007). While social impairments or differences are core diagnostic features of ASD, significant variability in the extent of such social-developmental deficits has been empirically observed between children who share this diagnosis (Charman et al., 2003; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Mundy, Gwaltney, & Henderson, 2010; Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007). This variation in degree of impairment in upstream causal factors could cascade across the development of multiple other domains downstream, beginning with language skills (Dawson et al., 1998, 2005). Investigating such *developmental cascades* involving social and language development in large representative cohorts of young children with ASD is, therefore, highly relevant to understanding developmental heterogeneity (Masten & Cicchetti, 2010). It may also inform the delivery of interventions that optimize child outcomes across multiple domains of symptoms and functioning.

Given what is known about the development of early language ability in children with and without ASD, early trajectories of social and language development may demonstrate reciprocally cascading interactions over time. Relative advantages in social competence (i.e., the degree to which a child demonstrates age-appropriate levels of social interest, social-cognitive skills and effective prosocial behavior) may lead to more proficient language learning either directly (e.g., pointing at and naming objects) or indirectly (e.g., overhearing conversations; Charman, 2003; Dawson et al., 1998; Mundy, Sigman, & Kasari, 1990; Parish-Morris et al., 2007). Enhanced language abilities, meanwhile, have been associated with higher scores on theory of mind tasks (Bennett et al., 2013; Hale & Tager-Flusberg, 2003) and more advanced play skills (Tager-Flusberg & Caronna, 2007), and may benefit social development as more linguistically competent children with ASD use their verbal skills to reason through social scenarios (Fisher, Happe, & Dunn, 2005). Thus, different skill pathways may interact and build off each other within the context of each child's development and experience of his/her environmental contexts in a reciprocal pattern. In this manner, children who have slight early developmental advantages may make greater gains, while others may fall further behind.

In studying potential developmental cascades, it is also important to consider whether other important child characteristics may modify the nature or extent of such processes. Children with ASD with and without comorbid cognitive impairment ('ASD/CI' vs. 'ASD/alone') represent clinically relevant subgroups – now outlined in the DSM-5 – that differ significantly with respect to functional outcomes (Anderson, Liang, & Lord, 2014; American Psychiatric Association, 2013; Bennett et al., 2014). Several researchers have argued that it is important to consider whether differential associations across developmental domains over time may distinguish between clinically relevant subgroups of children with developmental disabilities, particularly those who appear to compensate more successfully for early deficits (Thomas, Purser, & Van Herwegen, 2012). For example, Ferrer et al., (2007) found evidence of stronger associations ('stronger developmental coupling') between IQ and reading in children with dyslexia who seemed to compensate for initial deficits to became successful readers compared to children with dyslexia whose difficulties persisted more strongly. Analogously, SOC and LANG may be more weakly correlated among children with ASD/CI compared to those classified as ASD/alone. Cognitive impairment may reflect an added underlying genetic or epigenetic 'hit' that further disrupts dynamic interactions between the developmental pathways of different domains, for example by virtue of added barriers in the form of perceptual-spatial or processing speed deficits that undermine the transfer of learning from social interactions to language skills and vice versa (Elsabbagh & Johnson, 2010; Mundy et al., 2007). Without the added burden of cognitive impairment, children with ASD/alone may be able to better capitalize on early social competence to improve upon their language skills; the abilities in these two domains may therefore be more strongly linked across development in this cognitively higher scoring group. The additional burden of CI may thus moderate reciprocal relations between social and language learning over time. Such a moderating effect would have important implication for understanding differences in outcomes between clinically relevant subgroups of children with ASD as well as for targeted intervention.

Given the above, it is important to understand whether reciprocal effects occur between social competence (SOC) and language ability (LANG) early in the development of children with ASD, the extent to which they occur (strength of association) and whether such patterns differ between clinically important groups of children (i.e., children with ASD vs. those diagnosed with ASD/CI). To date, studies of ASD have not addressed such questions. We aimed, therefore, to examine more closely how these two domains influence each other from one time point to another during an important period in their development.

As part of a larger prospective multisite observational study of the development of children with ASD, we articulated three sets of hypotheses: (a) That language and social competence would exert reciprocal influences over time after accounting for the stability of each domain (how strongly social or language skills build on themselves over time), that is, greater baseline SOC (SOC_1) would be associated with stronger LANG measured 6 months later ($LANG_2$), which in turn would be associated with higher scores on SOC 12 months after baseline (SOC_3), and its complementary pattern (i.e., $LANG_1$-SOC_2-$LANG_3$); (b) Given the social impairment implicit in a diagnosis of ASD, and in keeping with the claims of social learning theories – that advantages in early social competence would predict higher language levels downstream – we expected a stronger association between SOC_1 and $LANG_2$ than between baseline $LANG_1$ and SOC_2; (c) Finally, we hypothesized that the group of preschoolers with ASD/CI would demonstrate weaker reciprocal effects between SOC and LANG than those meeting criteria for ASD/alone, as cognitive impairment would provide another constraint on their development.

Methods

Participants

Data were obtained from a Canadian multisite longitudinal inception cohort study of 2- to 4-year-olds diagnosed with any ASD [autistic disorder, Asperger Disorder, pervasive developmental disorder-NOS (PDD-NOS)] in the previous 4 months. Participants presented for initial assessment at regional ASD assessment centers affiliated with academic institutions in Halifax, Montreal, Toronto, Hamilton, Edmonton, and Vancouver. Inclusion criteria comprised: diagnosis of ASD or autistic disorder, Asperger Disorder or PDD-NOS as determined by clinical judgment of an interdisciplinary team with diagnostic expertise according to criteria set out by the Diagnostic and Statistical Manual, Text Revision, 4th Ed .(DSM-IV-TR; American Psychiatric Association, 2013); fulfillment of criteria for ASD according to both the Autism Diagnostic Observation Scale (ADOS; semistructured standardized assessment of the child; Lord et al., 2000, 2002) and Autism Diagnostic Inventory-Revised (ADI-R; semistructured parent interview, Lord, Rutter & Le Couteur, 1994) using the Risi et al., (2006) criteria. Exclusion criteria were: a known genetic syndrome or neurological basis for disorder and parents who did not speak English or (in Montreal) French (i.e., prohibiting engagement in testing). Informed consent was obtained from parents. Ethics approval was obtained from each institutions research ethics board.

Children and families were assessed at three time points using a battery of measures at baseline time of diagnosis (T1), 6 months- (T2) and 12 months (T3) later. Assessments of social competence (i.e. VABS-II) were completed by 359 families (98.4%) at T1, 315 families at T2 (86.3%), and 298 at T3 (81.4%). The language measures [Preschool Language Scale -4 (PLS-4) and Clinical Evaluation of Language Fundamentals (CELF)] were completed by 345 participants (94.5%) at T1, 312 (85.5%) at T2, and 291 (79.7%) at T3. Thirty-five families dropped out of the study after enrollment, and 18 did not complete T2 data due to scheduling or other reasons, but returned for T3. Children were included if they provided data for at least one time point. There were no differences between study completers and those who dropped out based on child age at diagnosis, ADOS severity score, Vineland Adaptive Behavior Composite score or PLS-language Auditory Comprehension (AC) and Expressive Communication (EC) scores at T1 (*t*-test, $p > .05$). However, 15.0% of families with annual incomes below $80,000 (CAD) withdrew, compared to 5.2% of those with annual incomes above $80,000 ($\chi^2 = 6.78$ [1], $p < .01$).

Measures

The *ADI-R* (Lord et al., 1994) is a semistructured parent interview that assesses developmental abilities and behaviors related to DSM-IV-TR diagnostic criteria for ASD (American Psychiatric Association, 2013). Items are scored from 0 (no autism-specific abnormality present) to 3 (extreme abnormality indicative of autism).

The *ADOS* (Lord et al., 2000, 2002) is a semistructured, standardized assessment in which a trained clinician engages a child in activities developed to assess social and communication behaviors indicative of DSM-IV-TR symptoms of ASD (American Psychiatric Association, 2013).

The *Preschool Language Scale-4th Edition (PLS-4;* Zimmerman, Steiner & Pond, 2012) is an individually administered test used to identify children with language impairment. It provides scores for Total Language (TL), Auditory Comprehension (AC), and Expressive Communication (EC) for children from birth through age 6 years, 11 months, or those who are functioning developmentally in that range. The AC subscale evaluates how much a child understands, and targets nonverbal skills such as attention to speakers as well as basic vocabulary, concepts, and grammatical markers. The EC subscale assesses how well a child communicates with others, and includes assessment of vocal development in infants and toddlers. Research staff continued testing a child until a ceiling was reached according to testing guidelines; should a child progress without reaching a ceiling at a given time point (i.e., beyond the limits of the PLS-4), then the *Clinical Evaluation of Language Fundamentals CELF;* (Semel, Wiig, & Secord, 2003) was also administered. At the following time point, the child was then only administered the *CELF*. At T2, 12 children (3.2%) and at T3 30 children (8.2%) 'outgrew' the PLS-4 in this manner. To account for these children without losing their data (and thus biasing analyses), their PLS-4 scores were considered to be censored ('missing') and LANG scores were imputed using multiple imputation procedures. To facilitate interpretation of the analyses, raw scores were used in the model, while standardized scores were used in tables that describe the overall sample.

The Vineland Adaptive Behavior Scales, Second edition (VABS-II; Sparrow, Cicchetti, & Balla, 2005) is a semistructured interview that measures an individual's strengths and weaknesses in socialization, communication and daily living skills in children aged 0–18 years, 11 months. Higher scores demonstrate superior adaptive behavior skills. The VABS-II is designed to capture a broad scope of developmental abilities. In the interview, parents indicate whether a child is able to demonstrate a given skill, and their responses are scored on a scale from zero (no, never) to 2 (yes, usually). The Socialization subdomain scales used in this study were: Interpersonal Relationships ('How the individual interacts with others', 38 items reflecting abilities such as looking at a caregiver's face, showing affection, delayed imitation of a complex task etc.), Play and Leisure Time ('How the individual plays and uses leisure time', 31 items including 'showing an interest in new objects or new people', 'showing interest in the activities of others' etc.) and Social Coping Skills ('How the individual demonstrates responsibility and sensitivity to others', 30 items, such as 'says please…', 'follows community rules'). Raw scores were used in the model and analyses to facilitate interpretation of associations between SOC and LANG domains, while standardized scores were used to describe scores within the sample.

The *Merrill-Palmer-Revised Scales of Development* (M-P-R; Roid & Sampers, 2004) is an individually administered measure of intellectual development that is appropriate for children aged 2–78 months. It was designed to measure fluid reasoning, crystallized cognitive ability, short-term memory, processing speed and visualization. Scores on the M-P-R correlate strongly with other measures of intellectual ability, including comparable subscales of the Bayley Scales of Infant Development (Roid & Sampers, 2004). The Cognitive Domain standard score (mean = 100, *SD* = 15) is a measure of nonverbal intellectual ability (i.e., comparable to performance IQ), and comprises nonverbal reasoning skills such as categorization, sorting and inductive reasoning. To characterize children with and without comorbid intellectual disability, two subgroups were created to compare children who scored below vs. above a cut-off of 70 standard score points (respectively referred to as ASD/CI [$n = 265$] and ASD/alone [$n = 100$]).

Analyses

Measurement model. Longitudinal cross-lagged models – also known as reciprocal effects models (Marsh, Trautwein, Ludtke, Koller, & Baumert, 2005) – were developed using structural equation modeling with data from three time points: baseline (within 4 months of diagnosis, or T1), 6 months- (T2) and 12 months (T3) later. Two variables represented social competence (SOC) and language ability (LANG) from T1 to T3 (labeled $SOC_{1–3}$ and $LANG_{1–3}$). The observed scores of the VABS-II Socialization domain subscales – Interpersonal Relationships, Play and Leisure, and Social Coping were used as indicators to develop a latent SOC variable that represented the variance shared between the scores. Disturbance terms (labeled 'd') at T2 and T3 represent residual or unexplained variance in SOC variables. Error terms ('e') represent the residual variance in a given observed VABS-II subscore (e.g., Interpersonal Relationships, VABS-IR) that is not shared with the other subscores (i.e., Play and Leisure Time, Social Coping; see Figure 1). Analysis of temporal and multigroup invariance indicated that the structure of the latent variable did not vary significantly across time points between children with ASD/alone and ASD/CI.

The PLS-4 was used to develop a latent variable for early language ability, using the AC and EC subscale scores as indicators. However, the indicators were highly collinear (correlations between AC and EC subscales within each time point ranged from $r = .90$ to .92). Since both subscales loaded so highly on the latent factor that either could adequately represent the LANG construct, the AC subscale was arbitrarily chosen. Thus, LANG was represented by a measured, rather than latent, variable. Similar to the SOC variable, error terms ('e') represented the residual variance in the AC subscale at a given time point (e.g., $LANG_2$) that was unexplained by associations outlined in the model. For SOC and LANG variables, error covariance linking residual error terms for the same indicators over time were allowed to vary freely in this study (i.e., they were not constrained to equal each other). For detail, see Appendix S1.

Structural model. The cross-lagged structural model, also known as path analysis, builds on the above measurement model by examining linear relations between the $SOC_{1–3}$ and $LANG_{1–3}$ variables (see Figure 1). To examine reciprocal associations between SOC and LANG, the model outlines a series of regression associations: (a) stability paths linking the same construct across time points (i.e., SOC_1-SOC_2 and SOC_2 to SOC_3); (b) cross-domain correlations measured at one time point (i.e., SOC_1-$LANG_1$); and (c) cross-lagged paths from one construct at a given time point (e.g., SOC_1) to the other at the following time point (e.g., $LANG_2$; see Figure 1). Thus, cross lagged models enable one to test for reciprocal cross-domain associations (e.g., SOC_1-$LANG_2$) while controlling for earlier auto-regressive effects of SOC or LANG building on themselves over time (e.g., SOC_1-SOC_2).

The strength and statistical significance of each regression weight parameter were estimated, as was the overall goodness of fit of the model. The following goodness of fit tests were used: the Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI; values ≥ 0.95 = excellent fit), the Root Mean Square Error of Approximation [values ≤ 0.05 = excellent fit, 0.05–0.09 = good fit, and over 0.10 = inadequate fit (Hu & Bentler, 1999)]. The chi-square test of fit is often considered to be excessively stringent in the presence of large sample sizes, but was included for completeness (Cheung & Rensvold, 2002); non-significant chi-square values ($p > .05$) generally reflect good to excellent fit.

To test hypothesis (1), that longitudinal reciprocal associations would be evident between SOC and LANG, the hypothesized reciprocal model was compared to a null model, which specified a complete absence of all cross-lagged effects (e.g., SOC_1-$LANG_2$ = 0; $LANG_1$ to SOC_2 = 0; SOC_2-$LANG_3$ = 0; $LANG_2$-SOC_3 = 0). The presence of significant cross-lagged parameter estimates, controlling for the auto-regressive stability associations (e.g., $LANG_1$-$LANG_2$-$LANG_3$), and a significantly superior fit ($p < .05$) for the hypothesized model over the null model would support our initial hypothesis that reciprocal cross-lagged associations exist between SOC and LANG over time. To test hypothesis (2), the estimates of the strength of cross-lagged path from SOC_1 to $LANG_2$ versus $LANG_1$ to SOC_2 were compared by examining the size and statistical significance of the unstandardized estimates, and also by constraining the strength of the paths SOC_1-$LANG_2$ and $LANG_1$-SOC_2 to equal each other. A significant improvement of the model's fit, represented by a significant change in the χ^2 value ($\Delta\chi^2$, $p < .05$) when relaxing the constraints (i.e., reverting to the hypothesized model) would indicate that the two paths were not equally strong.

Multigroup comparisons were then performed to determine whether the cross-lagged associations outlined in the hypothesized model differed between children classified as ASD/alone versus ASD/CI as outlined by hypothesis (3). The fit of a nested model in which the parameters of interest were constrained to equivalence between the two subgroups was compared to the baseline hypothesized model in which the parameters were free to vary. A significant difference in χ^2 values ($\Delta\chi2$, $p < .05$) would indicate significant differences in the size of the parameters.

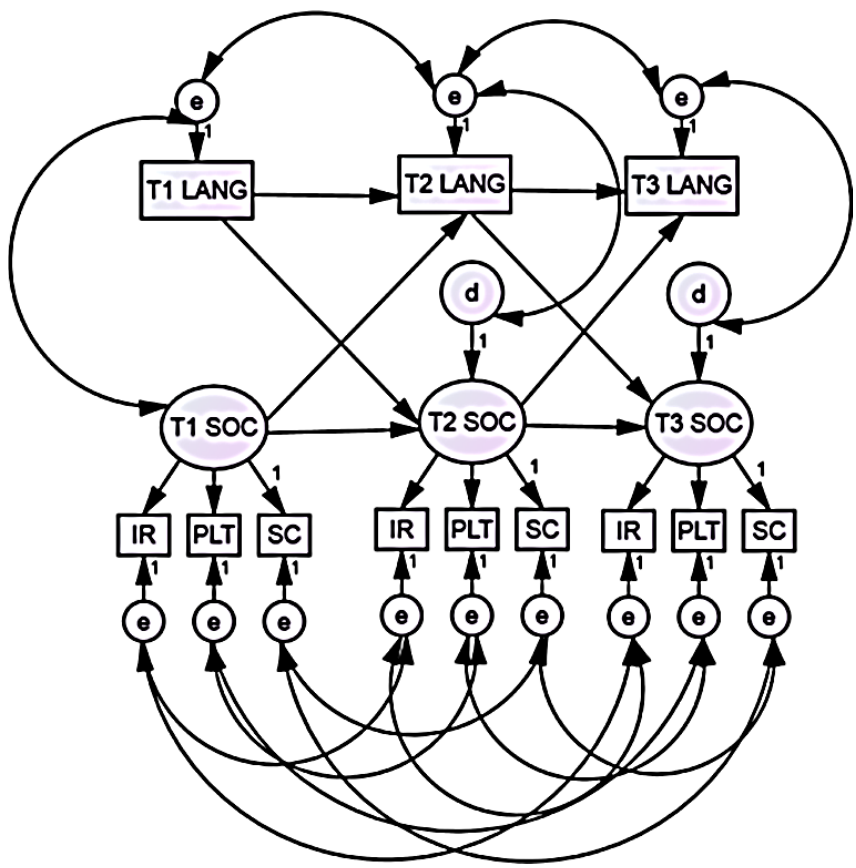

Figure 1 Cross-lagged model. e = measurement error; d = disturbance (residual error); IR = VABS-II Interpersonal Relationships; PLT = VABS-II Play and Leisure time; SC = VABS-II Social Coping. SOC = Social Competence (as measured by VABS-II Socialization Subscales). LANG = Language Ability (as measured by PLS-4 Auditory Comprehension Subscale)

The following parameters were examined: a) baseline correlations between SOC_1 and $LANG_1$; and b) individual cross-lagged regression paths across all time points (SOC_1-$LANG_2$; $LANG_1$-SOC_2; SOC_2-$LANG_3$; $LANG_2$-SOC_3).

AMOS 17.0 was used for model estimation using maximum likelihood estimation (Arbuckle, 2006). Multiple imputations were used to account for missing data, with five imputed datasets created (Appendix S2). Because AMOS does not pool goodness-of-fit estimates across imputed datasets, the range of fit estimates is reported for the model across datasets. The size of parameter estimates was arbitrarily considered to differ significantly between ASD/CI and ASD/alone subgroups if a constrained model was found to represent a significantly worse fit to the underlying data in at least 4/5 datasets. Unstandardized regression coefficients were used to compare strength of estimates, and are reported as such unless otherwise specified.

Results

Hypothesized structural model, entire group

For a baseline description of the participants, see Table 1. For bivariate correlations of all variables, see Table S1.

The hypothesized reciprocal effects model demonstrated an excellent fit to the underlying data (*CFI* = 0.99–1.0; *TLI* = 0.99; *RMSEA* = .03–.05), and explained a substantial amount of variance in SOC (77.3%) and LANG (81.8%) at T3. Social competence and language were moderately to highly correlated at baseline (ϕ = 56.18 [5.32], $r = .74$, $p < .01$). The cross-domain T2 correlation was smaller (ϕ = 11.79 [2.40], $r = .35$, $p < .01$), and the T3 correlation was not significantly different from zero (ϕ = 5.54 [3.72], $r = .16$, $p = .17$; see Table 2 and Figure 2). Analysis of the patterns of regression associations within and between SOC and LANG across T1 to T3 yielded the following results: First, SOC and LANG were highly stable. An increase of 1 *SD* in SOC_1 was associated with an increase of 0.47 *SD* in SOC_2, and an increase of 1 *SD* in SOC_2 was associated with an increase of 0.78 *SD* in SOC_3 (see Table 2). Stability was also high for LANG: An increase of 1 *SD* in $LANG_1$ was associated with an increase of 0.79 *SD* in $LANG_2$, and an increase of 1 *SD* in $LANG_2$ was associated with an increase of 0.80 *SD* in $LANG_3$ ($p < .01$). Analyses of the stability paths indicate that children who scored highest on the VABS-II Socialization and PLS-4 subscales at T1 tended to remain higher scoring in these domains at T3 relative to the other participants. In other words, the relative ranking of participants within the sample changed little with respect to SOC and LANG in the year after ASD diagnosis.

Despite the high stability of SOC and LANG constructs over time, with respect to our first hypothesis, small and positive but statistically significant cross-lagged paths were found in both

Table 1 Baseline (T1) sample characteristics

Age at diagnosis in months (mean, *SD*, range)	Merrill-Palmer Cognitive Score (mean, *SD*, range)	VABS Social Standard Score (Mean, *SD*, range)	PLS-4 Expressive Communication Standard Score (Mean, *SD*, range)	PLS-4 Auditory Comprehension Standard Score (Mean, *SD*, range)	ADOS Severity Metric (Mean, *SD*, range)
38.21 (8.48) 23.44–59.57	57.29 (24.65) 10–150	72.24 (9.02) 49–103	65.12 (19.89) 10–150	69.78 (17.13) 10–133	7.67 (1.65) 4–10

Table 2 Unconstrained cross-lag model, entire sample

	Parameter estimate (*SE*)	Standardized parameter estimate	*p*-value
Regression coefficients (B)			
T1 Social competence → T2 Social Competence	0.64 (0.09)	0.47	$p < .01$
T2 social competence → T3 social competence	0.79 (0.14)	0.78	$p < .01$
T1 language → T2 language	0.92 (0.05)	0.79	$p < .01$
T2 language → T3 language	0.86 (0.06)	0.80	$p < .01$
T1 social competence → T2 Language	0.25 (0.08)	0.13	$p < .01$
T1 language → T2 social competence	0.27 (0.05)	0.37	$p < .01$
T2 social competence → T3 Language	0.21 (0.09)	0.14	$p = .02$
T2 language → T3 social competence	0.12 (0.07)	0.16	$p = .12$
Covariance parameters			
ϕ SOC_1-$LANG_1$	56.18 (5.32)	$r = .74$	$p < .01$
ϕSOC_2-$LANG_2$	11.79 (2.40)	$r = .35$	$p < .01$
ϕSOC_3-$LANG_3$	5.54 (3.72)	$r = .16$	$p = .12$

Goodness of fit tests	χ^2, 42 *df*	*CFI/TLI*	*RMSEA* (CI)
Imputation #1	67.74, $p < .01$	0.99/.99	.04 (.02–.06) $p_{close} = .79$
Imputation #2	59.84, $p = .04$	1.0/.99	.03 (.01–.05) $p_{close} = .92$
Imputation #3	55,13, $p = .08$	1.0/.99	.03 (.00–.05) $p_{close} = .96$
Imputation #4	55.17, $p = .08$	0.98/.98	.03 (.00–.05) $p_{close} = .96$
Imputation #5	75.43, $p < .01$	0.99/.99	.05 (.03–.06) $p_{close} = .60$

ϕ = covariance; r = correlation.

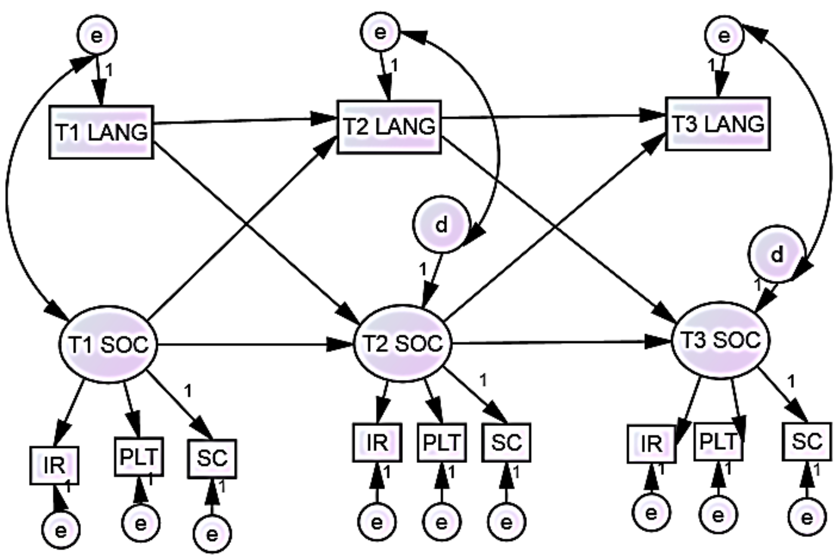

Figure 2 Cross-lagged model with estimates. Only statistically significant associations noted ($p < .05$). N.B. correlations between error and disturbance terms omitted to simplify model. e = measurement error; d = disturbance (residual error); IR = VABS-II Interpersonal Relationships; PLT = VABS-II Play and Leisure time; SC = VABS-II Social Coping. SOC = Social Competence (as measured by VABS-II Socialization Subscales). LANG = Language Ability (as measured by PLS-4 Auditory Comprehension Subscale); r = correlation coefficient; B = standardized regression coefficient

directions across most time points (see Table 2). For example, an increase of 1 *SD* in SOC_1 was associated with an increase of 0.13 *SD* in $LANG_2$, and an increase of 1 *SD* in $LANG_1$ was associated with an increase of 0.37 *SD* in SOC_2. SOC_2 was then positively and significantly associated with $LANG_3$ [$B = .21$ ($SE = 0.09$), $p = .02$; standardized $\beta = .14$]. However, $LANG_2$ was not significantly associated with SOC_3 [B = .12 (SE = 0.07), p = .12]. There was a significant worsening of fit of the model (in comparison to hypothesized reciprocal effects model) when cross-lagged paths were constrained to zero; the chi-squared difference tests were statistically significant in all imputed datasets, ranging from 75.57 (4 *df*; $p < .01$) to 94.69 (4 *df*; $p < .01$). Thus, statistically significant cross-lagged effects were evident from SOC to LANG across all time points and from $LANG_1$ to SOC_2. This pattern supported the first hypothesis that reciprocal effects were evident between SOC and LANG domains, with the important caveat that the size of reciprocal associations was small. Our second hypothesis was not supported; that is, comparison of nested models failed to indicate significant differences in strength between reciprocal SOC_1-$LANG_2$ and $LANG_1$-SOC_2 (chi-squared tests of difference ranged from .03 [1 *df*], p = .96 to .18 [1 *df*], p = .67). SOC and LANG, as measured in this study near time of diagnosis of ASD, were each equally strong predictors of the other domain as measured 6 months later.

There were no significant differences in the strength of reciprocal cross-lagged effects between children who differed by cognitive status with two exceptions. First, $LANG_1$ was more strongly associated with SOC_2 in children classified as ASD/CI compared to those with ASD/alone, albeit in 4/5 datasets, which suggests that the magnitude of the differences were small and hovering around statistical significance ($\Delta\chi^2$ (1 *df*) = 2.96, p = .09 to 5.29, p = .02). Second, across all datasets baseline correlations between SOC_1 and $LANG_1$ were significantly stronger among children with ASD/alone compared to the ASD/CI subgroup (range of $\Delta\chi^2$ [1 *df*] = 5.41, p = .02 to 7.68 [1 *df*], $p < .01$).

Discussion

This study aimed to determine whether social competence and structural language abilities were reciprocally related in the first year after diagnosis of very young children with ASD. We found that each domain was highly stable. Children who at time of diagnosis scored either high or low on social competence or language ability relative to the rest of the sample were likely to maintain this standing over the ensuing assessments 6- and 12 months later. Although significant reciprocal effects were found between social competence and language ability across most time points, they were generally small. Furthermore, within-time correlations between social competence and language at each time point became progressively weaker over development. Contrary to our hypothesis, the associations between baseline language and later social competence did not appear to differ in strength compared to those from social competence to later language. Finally, there were no significant differences in the cross-lags between ASD/alone and ASD/CI subgroups with two exceptions: social competence and language factors were more strongly correlated at baseline in children classified as ASD/alone, and language ability at T1 was more strongly associated with social competence at T2 in children with ASD/CI.

Evidence that the associations between social competence and language are small and appear to be weakening over time does not support a reciprocal cascades model of development in the year after diagnosis. Rather, this pattern of findings is more consistent with two developmental pathways that are becoming more independent over time, as abilities become more specialized and build upon themselves. Indeed, the auto-regressive associations emphasized the significant stability of social competence and language as measured in this study in the first year after diagnosis. This resembles a recent study's findings that typically developing children demonstrated very stable language skills between the ages of 20 and 48 months (Bornstein, Hahn, Putnick, & Suwalsky, 2014).

Contrary to our initial hypothesis, analyses did not support a stronger association between baseline social competence and language 6 months later compared to its opposite, baseline language to later social competence. This differs from previous experimental findings (Kuhl, Coffey-Corina, Padden, & Dawson, 2005). This may reflect differences in sampling (i.e., broader age range of preschoolers with ASD) or measurement (i.e., the VABS-II, rather than a more specific, observational measure of social attunement).

Furthermore, contrary to our initial hypothesis, children with ASD/alone did not demonstrate stronger cross-domain reciprocal associations after baseline compared to children with ASD/CI. However, significantly stronger baseline correlations between social competence and language at time of diagnosis were evident among children with ASD/alone. Thus, nonverbal cognitive ability therefore appears to moderate this baseline cross-domain association. A possible inference from this study's findings is that children with ASD/alone who lack the 'added hit' of comorbid cognitive impairment may benefit from greater cross-domain developmental cascades prior to subsequent specialization of social and language pathways. This may reflect processes of brain adaptation that restore a developmental trajectory to one that is more normative (i.e., 'higher-functioning' socially, linguistically; Elsabbagh & Johnson, 2010).

Children with ASD/CI also appeared to demonstrate stronger relations between baseline language ability and social competence 6 months later compared to those with ASD/alone. A recent study using the same dataset found that children with ASD/CI in this sample had lower baseline social competence scores on the Vineland and made fewer gains over 12 months than those with ASD/alone (Bennett et al., 2014). Furthermore, 30% of children with ASD/CI 'moved' to the nonimpaired (but generally low average) range of cognitive ability 12 months later, suggesting that they represented a group with developmental delay rather than persistent intellectual disability (Bennett et al., 2014). The stronger longitudinal relation between language and social competence in the ASD/CI group in this study may thus reflect a compensatory process whereby children with less severe cognitive impairment develop 'enough' language to scaffold further social skill development. However, these subgroup findings require replication. It will also be important to examine the role of cognitive ability as a dimensional rather than categorical variable to parse the longitudinal relations between language, cognitive and social domains in a more nuanced way.

The results of this study may inform intervention practice and policy in the following ways: First, the strong stability and decreasing interrelatedness of social and language development after preschool diagnosis (i.e. at age 3–5 years) highlights the importance of intervention programs that target both social competence and language development, as advances in one domain may not drive advances in the other among children diagnosed with ASD (Dawson, 2008; Dawson & Zanolli, 2003; Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012). Secondly, further research will be required to compare whether interventions delivered during certain development periods yield stronger cascade effects than others (e.g., toddler vs later preschool years). For example, intervention may yield stronger 'spillover' effects across developmental domains if it targets all toddlers with delays or atypicalities in emerging social competence or language, even before a subset of these may get a diagnosis of ASD at a later time. Such efforts would require significant public investments into early detection and intervention across neurodevelopmental disorders (e.g., ASD, global developmental delay, language impairment), and research into their effectiveness.

Several limitations exist. First, the findings are correlational and do not provide conclusive evidence of causal associations. Secondly, latent variables should ideally be constructed from multiple measures. Some method or informant effects may have influenced the results, although this is likely less problematic across lags of 6 months. Third, we were unable to covary service uptake by children, however, we would not expect this to affect our questions of interest. Fourth, because of software limitations, an arbitrary decision was made to consider models as significantly different if chi-squared difference tests were statistically significant across 4/5 datasets. Because multiple paths or associations within the same model were tested separately for differences between ASD/CI and ASD/alone groups, it will be important to replicate these subgroup analyses. Fifth, the time lags in this study may be too short or too long to detect stronger reciprocal associations. Finally, it is also possible that stronger cross-domain effects would have been detected using other measures. However, the early social skills assessed by the VABS-II reflect milestones that have typically been linked to language development (e.g., imitation, attunement to others). Furthermore, neither the VABS-II nor the PLS-4 raw scores, in this study, demonstrated significant floor effects to suggest that the decreasing cross-domain associations over time might be related to measurement artifact for these reasons.

Future studies may build upon these findings. First, despite several social learning theories of language, to our knowledge there are no cross-lagged reciprocal effects studies of social competence and language ability in typically developing children. To examine the specificity of this pattern to children with ASD, it would be important to replicate this study using typically developing controls. Second, extending studies of developmental cascades in children with ASD earlier to capture emerging processes in at-risk populations (e.g., infant siblings of children with ASD) and later into childhood would enable researchers to examine larger patterns of effects between these and other domains across developmental periods, and to link these to relevant 'real-world' outcomes, such as peer relationships, comorbid mental health and academic or vocational success. Understanding when developmental cascades occur and how they are influenced by child, family, and contextual factors will be important to the provision of more effective and developmentally sensitive interventions.

In conclusion, early social competence and language ability in children recently diagnosed with ASD are strongly correlated at time of diagnosis. These domains then appear to develop more independently rather than building off each other reciprocally to any large extent. Children with ASD and better-developed cognitive abilities may have received some developmental benefit from earlier cross-domain associations in the period prior to diagnosis. Future research might address this issue by studying high-risk infants and control groups. Overall, reciprocal cascade models are promising analytic tools for comparing the relative dependence and independence of different developmental domains across the life span in ASD. This in turn may guide the implementation of more developmentally sensitive interventions.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Details of measurement model.

Appendix S2. Overview of multiple imputation procedure.

Table S1. Bivariate correlations of variables included in model.

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Key points

- Developmental cascades – how skills or milestones attained in differing developmental domains may influence each other over time within individual children – are useful models for understanding the heterogeneity of symptoms and functioning over time in autism spectrum disorder (ASD).
- In an inception cohort study of children aged 2–4 years with ASD, social competence and language ability, measured 6 months apart, demonstrated only small reciprocal associations in the year after diagnosis.
- Overall, social and language skill pathways were very stable, and appeared to become more independent and less interrelated over time in preschoolers with ASD.
- Differences were not detected in the strength of longitudinal associations from social competence to language ability and vice versa.
- Interventions aimed at preschool-aged children already diagnosed with ASD may optimize outcomes if they target both social competence and language ability, since it is not clear that progress in these domains are strongly and reciprocally related overtime.

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