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Associations Between Syntax and the Lexicon Among Children With or Without ASD and Language Impairment

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Abstract Five groups of children defined by presence or absence of syntactic deficits and autism spectrum disorders (ASD) took vocabulary tests and provided sentences, definitions, and word associations. Children with ASD who were free of syntactic deficits demonstrated age-appropriate word knowledge. Children with ASD plus concomitant syntactic language impairments (ASDLI) performed similarly to peers with specific language impairment (SLI) and both demonstrated sparse lexicons characterized by partial word knowledge and immature knowledge of word-to-word relationships. This behavioral overlap speaks to the robustness of the syntax–lexicon interface and points to a similarity in the ASDLI and SLI phenotypes.

Keywords Autism · Specific language impairment · Syntax · Lexicon

Introduction

By definition, autism spectrum disorder (ASD) and specific language impairment (SLI) are distinct developmental disorders; however, any clinician can recall cases that made for a difficult differential diagnosis. The literature is replete with evidence that these two diagnostic categories overlap in phenotypic profiles and recent evidence of partially shared genotypes (see review in Bishop 2010) motivates more precise description of this overlap and its limits. In the current study, we aimed to elucidate the relationship between syntax and lexical semantics in children with ASD and SLI thereby furthering comparisons of the two populations and informing debates over the extent of their overlap.

Children with SLI present with delays in language development in the absence of ASD, mental retardation, hearing impairment, or other obvious causes. As a group, they have greater deficits in syntax than lexical semantics and greater deficits in lexical semantics than pragmatics (Tomblin and Zhang 1999). In fact, 85% of children with SLI present with better pragmatics than syntax and semantics (Tomblin et al. 2004). Their syntactic deficits are characterized by reduced utterance length (e.g., Bedore and Leonard 1998), omission of grammatical morphemes, especially those marking tense, agreement, and aspect (e.g., Miller et al. 2008; Rice et al. 1998), problems with syntactic operations (e.g., Johnston and Kamhi 1984), and limited knowledge of argument structure (e.g., King and Fletcher 1993). One influential account of SLI attributes the associated language deficits to limitations in phonological short-term memory (Gathercole and Baddeley 1990). Limitations on the amount of phonological information that can be held in the short-term store reduce language learning, comprehension, and use. Such limitations, typically assessed by determining the accuracy of imitation of nonwords of increasing lengths, are considered a clinical marker of SLI (Conti-Ramsden et al. 2001).

Syntax is a relative strength for verbal children with ASD. Instead, pragmatics is the domain of greatest weakness (Rice et al. 2005). Affected individuals have difficulty coordinating attention between a partner and an object, entity, or event in the environment (e.g., Lewy and Dawson

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1992). In conversation, they often make perseverative comments and misjudge the needs of their partner (e.g., Tager-Flusberg and Anderson 1991). Some have attributed these problems to deficient theory of mind or difficulty considering others' mental states (Baron-Cohen 1989); others to weak central coherence or difficulty integrating information into a meaningful whole (Frith 1989).

The contrast between the language profiles of SLI and ASD is evident: Those with SLI have a relative weakness in syntax and a relative strength in pragmatics. The reverse is true of those with ASD. Nevertheless, these distinctions are not nearly so crisp in all cases. Some individuals with SLI demonstrate pragmatic language deficits and social awkwardness (Conti-Ramsden et al. 2006; Mawhood et al. 2000). Of 45 children presenting with a diagnosis of SLI, 41% also met clinical cut-offs for the identification of ASD on the social or communication domains of the Autism Diagnostic Interview or the Autism Diagnostic Observation Schedule, or both (Leyfer et al. 2008). Upon detailed examination, such children are not found to be misdiagnosed cases of autism, rather, they seem to fall on a continuum between ASD and more typical cases of SLI (Bishop and Norbury 2002). Some have described this subgroup as having "PLI," pragmatic language impairment (Bishop 2000).

There is accumulating evidence that there is also a subgroup of children with ASD who present with syntactic deficits akin to those that characterize SLI (Kjelgaard and Tager-Flusberg 2001). We shall refer to these children as having ASDLI. As in SLI, syntax is more deficient than lexical semantics (Eigsti et al. 2007; Kjelgaard and Tager-Flusberg 2001). Omission of morphemes that mark tense and reduced phonological memory span as assessed by nonword repetition tasks are reliable clinical markers in both groups as well (Kjelgaard and Tager-Flusberg 2001; Roberts et al. 2004). Similarities do not end there. In a comparison of children affected by SLI, ASDLI, or ASD without concomitant structural language impairments, the SLI and ASDLI groups did not differ from each other and each performed significantly more poorly than the ASD group on verbal-, performance-, and full-scale IQ, receptive vocabulary, and reading (Lindgren et al. 2009).

Current debate on the phenotypes of ASDLI and SLI centers on the extent of their overlap. Although Kjelgaard and Tager-Flusberg (2001) found nonword repetition to be problematic for both groups, their error patterns on that task differ (Riches et al. 2011; Whitehouse et al. 2008). There are also differences in the course of structural language development with a temporary language loss after an initial period of seemingly normal language development affecting 15% of those with ASD but virtually no children with SLI (Pickles et al. 2009). Moreover, the rates of language impairment in family members of children with SLI and those with ASDLI are clearly different with a higher rate being characteristic of those with SLI (Bishop 2010). The status of the debate is best exemplified by comparison of two recent reviews, one of which emphasized the similarities between the SLI and ASDLI populations (Groen et al. 2008), another which emphasized their differences (Williams et al. 2008).

We sought to inform this debate by moving beyond descriptions of strengths and weaknesses to descriptions of relationships between language domains. In particular, we asked whether both groups affected by syntactic deficits (ASDLI and SLI) also demonstrated shallow semantic lexicons and whether the severity of their syntactic deficits predicted the extent of such weaknesses. Conversely, we asked whether children without syntactic deficits (ASD and two normal comparison groups) demonstrated deeper semantic lexicons.

The focus on the syntax-lexicon relationship was motivated by their developmental linkage. Children leverage lexical knowledge in service of early syntactic development (Marchman and Bates 1994; Tomasello 2000) and, later, they use knowledge of morphosyntax to bootstrap new word meanings (Naigles 1990). The relative importance of lexical versus syntactic bootstrapping changes with development (Dionne et al. 2003) but the systems are not autonomous (Tomblin and Zhang 2006) and reciprocal support between the two systems likely continues in older learners when trying to comprehend complex syntactic constructions or new words with non-observable referents such as those labeled by verbs or abstract nouns. Consider, for example, that adults viewing a silent video of mother–child interaction can accurately guess 45% of the concrete nouns the mother utters but only 15% of the verbs. When given the syntactic frame (i.e., the word order and the grammatical function words that co-occur with the mystery verbs), guesses jump to 51.7% accuracy (Gillette et al. 1999).

Previous studies of young children with SLI provide another motivation for a focus on the syntax-lexicon relationship. Although syntactic deficits are a hallmark of SLI, as a group, affected children also have shallow lexical semantic representations (e.g., McGregor et al. 2002), and sparse semantic category knowledge (e.g., Simmonds et al. 2005). They may know a word well enough to identify its meaning in a supportive context but not deeply enough to use it accurately or flexibly in all contexts.

One recent study reveals shallow lexical knowledge among children with ASDLI as well. In Norbury (2005) children with ASDLI performed like children with SLI and both were less able than ASD and unaffected age-mate groups to identify secondary word meanings and were less efficient in using semantic context to do so. Children with ASD but no syntactic language impairment performed similarly to unaffected age-mates. This pattern was recapitulated in a study of comprehension of words in sentence contexts (Brock et al. 2008). Context effects did not differ for groups defined by presence or absence of ASD; however, when redefined by syntactic ability, those with syntactic deficit demonstrated reduced context effects compared to those without. These patterns suggest that shallow lexicons, and broader problems with lexical comprehension, are associated with the syntactic deficits that also affect part of the ASD population rather than the social or cognitive deficits that affect the population as a whole.

Depth of Lexical Semantics

The current study builds on these findings by introducing additional measures of lexical depth. Whereas breadth refers to the number of words in the lexicon, depth refers to the richness with which a given word is represented. As depth accrues, words can be used flexibly in multiple contexts (Anderson and Freebody 1981; Stahl 1998). Gradually that knowledge becomes decontextualized; decontextualization is considered integral to the deepening of lexical knowledge (Vygotsky 1962).

No task fully isolates breadth from depth (Vermeer 2001). However, tasks that require pointing to a pictured referent when it is named and those that require naming a pictured referent when it is presented are more likely to measure breadth of word-to-referent knowledge whereas tasks that require knowledge of word-to-word relationships such as recognizing or providing definitions, synonyms, or word associations are more likely to measure depth of word meaning.

Scoring methods too vary in sensitivity to breadth and depth. Those that estimate knowledge in a binary manner—right/wrong, known/unknown—are more likely to capture breadth (Dockrell and Messer 2004). Scores that rate precision, completeness, or developmental level of responses are more likely to capture depth. The amount of information included in verbal definitions is a gold standard measure of depth (Schoonen and Verhallen 2008). On word association tasks, responses that reflect paradigmatic (within category) relationships (e.g., *dog-cat*) are taken as a sign of greater depth than those that reflect thematic (within event) relationships (e.g., *dog-bone*) (Schoonen and Verhallen 2008). Paradigmatic relationships characterize the semantic lexicons of older children more so than younger children (Nelson 1977); children with normal language development more so than those with impaired development (Sheng and McGregor 2010); and native speakers more so than second language learners (Verhallen and Schoonen 1993).

Depth of lexical semantics increases during the school years (Dockrell and Messer 2004); at the same time, breadth becomes so great that it is difficult to estimate accurately. Therefore, although lexical breadth correlates highly with syntactic ability in early language development (Fenson et al. 1994); we reasoned that, by school age, measures of depth will be more sensitive to the syntax-lexicon relationship.

Current Study

We compared depth of lexical knowledge and associations between syntax and the lexicon among 9-to-14-year-old children on the autism spectrum (ASDLI and ASD) or the SLI spectrum as well as unaffected peers who were age-mates (AM) or younger syntax-mates (SM).

To confirm the syntactic deficits of the ASDLI and SLI groups, we administered a sentence production task and predicted that the ASDLI, SLI, and SM groups will produce sentences with fewer clauses than the ASD and AM groups. To obtain norm-referenced descriptions of lexical knowledge, we administered the Peabody Picture Vocabulary Test, Third Edition (PPVT-III, Dunn and Dunn 1997) and the Expressive Vocabulary Test, Second Edition (EVT, Williams 2007) and predicted that the ASDLI and SLI groups will present with lower standard scores than the other groups. To obtain a detailed profile of depth, we administered word definition and association tasks. Given the hypothesized links between syntactic and lexical ability, we predicted that the ASDLI, SLI, and SM groups, who have weaker syntactic skills, will perform more poorly on the definition and association tasks than the AM and ASD groups, who have stronger syntactic skills. The ASDLI, SLI, and SM groups will perform similarly to each other as will the AM and ASD groups. Given the special role of syntax in determining the meaning of verbs and abstract words that have unobservable referents, all groups will perform more poorly on verbs and abstract words than on nouns and concrete words. The children in the ASDLI, SLI, and SM groups will demonstrate a particularly large performance gap relative to the gap observed in the AM and ASD groups.

If social-pragmatic deficits that characterize ASD also relate to lexical depth, then alternative versions of predictions above would involve the ASDLI, SLI, SM, *and* ASD groups performing more poorly than the AM group and, given a double deficit, the ASDLI group performing more poorly than the SLI, SM, and ASD groups.

Method

Participants

We followed approved IRB protocols for treatment of human subjects.

Participants had normal hearing acuity and nonverbal intelligence as determined by passing scores on a pure-tone hearing screening administered per ASHA (1990) guidelines and standard scores of at least 85 on the matrices subtest of the Kaufman Brief Intelligence Test-2 (KBIT-2, Kaufman and Kaufman 2004), respectively.

The SLI group was composed of 9 boys and 5 girls, each included on the basis of an independent diagnosis of and services for oral or written language impairment via parent report (with the exception of one child who was home-schooled) and scaled scores <8 on the syntactic subtests (Formulated Sentences and Recalling Sentences) of the Clinical Evaluation of Language Fundamentals-4 (CELF4, Semel et al. 2003). Each child scored outside of the range of autism spectrum on the Social Communication Questionnaire (SCQ, Rutter et al. 2003).

The ASDLI group was composed of 12 boys each included on the basis of an independent diagnosis of and services for ASD via parent report and scores on the Autism Diagnostic Observation Schedule (ADOS, Lord et al. 1999) and the SCQ that met cutoffs for autism spectrum/autism disorders. They had scaled scores <8 on the syntactic subtests of the CELF4. The ASD group was composed of 19 boys and 2 girls. They met the same criteria for diagnosis of autism as the ASDLI group but their syntactic abilities were within normal limits as evidenced by scaled scores >7 on the syntactic subtests of the CELF4. On the ADOS the mean score of the ASD group was 13.21 (SD = 3.94) whereas the mean score of the ASDLI was somewhat higher (poorer) at 15.00 (SD = 4.22), $t = -1.20$, $df = 29$, $p = .24$. Subjects with ASD and ASDLI were recruited with assistance from the Interactive Autism Network Research Database at the Kennedy Krieger Institute and Johns Hopkins Medicine—Baltimore, sponsored by the Autism Speaks Foundation.

The SM group was composed of 14 boys and 12 girls. The AM group was composed of 27 boys and 24 girls. To be included in either, a child had to achieve scaled scores >7 on the syntactic subtests of the CELF4 and score outside of the range of autism spectrum on the SCQ. The AM group matched the SLI, ASDLI, and ASD groups in age in months (p's > .50); whereas the SM group matched the SLI and ASDLI groups in raw scores on the syntactic subtests of the CELF4 (p's > .50).

Demographic information and test data are summarized in Table 1. Although not used for selection purposes, three scores from the CELF4, the Working Memory, Receptive Language, and Expressive Language composites are included for descriptive purposes. On the measure of verbal working memory, 2 of the 12 participants with ASDLI scored poorer than one standard deviation below the mean as did 5 of the 14 participants with SLI. On the receptive language composite, 4 participants with ASDLI and 6 with SLI fell below this cut-off whereas, on the expressive

Table 1 Demographic and test data expressed as group means (and standard deviations)

Construct	Measure	SLI $n = 14$	ASDLI $n = 12$	ASD $n = 21$	SM $n = 26$	AM $n = 51$
Maturation/experience	Age in months	127.64 (19.35)	131.75 (28.91)	131.62 (25.66)	89.65 (25.86)	127.68 (22.88)
Syntax	CELF4 raw score[a]	77.71 (10.20)	75.50 (11.02)	137.48 (8.33)	78.96 (7.49)	124.65 (5.35)
Nonverbal cognition	KBIT2 matrices standard score	103 (10.00)	101 (12.07)	113 (12.31)	98 (21.15)	112 (10.55)
Socioeconomic status	Maternal education in years	14.93 (1.69)	15.67 (2.84)	16.81 (3.17)	15.73 (2.03)	15.63 (1.93)
Working memory	CELF4 WM standard score	83 (12.55)	93 (18.86)	104 (12.75)	108 (11.13)	110 (14.64)
Receptive language	CELF4 receptive standard score	86 (12.32)	83 (9.89)	111 (12.19)	113 (10.48)	114 (10.46)
Expressive language	CELF4 expressive standard score	75 (10.89)	69 (13.05)	108 (11.79)	108 (9.6)	115 (8.18)

[a] Raw scores on the Formulated Sentences and Recalling Sentences subtests of the CELF4 were summed to derive an estimate of syntactic ability

We matched the AM group to the clinical groups on the basis of age such that statistical comparisons yielded p values of at least 0.50. Likewise, the SM group was well-matched to the two clinical groups with limited syntax, SLI and ASDLI, according to raw scores on the syntactic subtests of the CELF4 with p values of .50 or greater. To facilitate comparison of their profiles, the SLI and ASDLI groups were well matched on age ($p = .67$), syntax ($p = .77$) and nonverbal cognition ($p = .61$). All other constructs were free to vary (with some restriction on the variance allowed for nonverbal cognition as measured by the KBIT2) language composite those numbers rose to 9 participants with ASDLI and 10 with SLI.

Stimuli

Four sets of 10 words were created by crossing word class (noun and verb) and meaning (concrete and abstract) (see Table 2). Words were designated concrete if their referents were readily observable and abstract if their referents were less observable. The latter were nouns and verbs that described mental states, feelings, communication, or events. Word classifications were confirmed by 10 adults: items that did not elicit >89% agreement were discarded. Thus, for example, "farm" was designated a concrete noun based on adult ratings although it can be a verb.

There were five low and five high frequency words in each of the four sets–concrete and abstract nouns and concrete and abstract verbs—to ensure that word class and meaning effects were not confounded with frequency of occurrence. Frequencies were calculated for the word and all variants (e.g., *stretch, stretches, stretched*, and *stretching* values were added to form a total value for *stretch*) using U scores (Zeno et al. 1995, p.15). Neither nouns and verbs, $F(1.32) = 0.15$, $p = 0.70$, nor concrete and abstract words, $F(1.32) = 0.0004$, $p = 0.98$, differed in frequency.

Stimuli were randomized once for each task and then administered in those particular orders to each participant. Tasks were administered in counterbalanced order. Task instructions, models, and prompts appear in "Appendix".

Sentence Production

Each child produced a sentence in response to each of the 40 target words. Sentences were transcribed and mazes (i.e., false starts and fillers such as "um") were omitted prior to analysis. A sentence was analyzed for syntactic complexity only if it included a verb and contained the target word used as the target word class. For each analyzable sentence, the number of clauses per sentence was determined.

Table 2 Stimuli classified by word class, concreteness, and frequency

	Noun		Verb	
	Concrete	Abstract	Concrete	Abstract
High frequency	chair	energy	eat	believe
	farm	fact	draw	consider
	machine	health	push	decide
	river	law	stretch	enjoy
	table	purpose	walk	love
Low frequency	carrot	emergency	fasten	advise
	coin	loyalty	pronounce	complain
	garage	mystery	shove	persuade
	helmet	origin	soak	suspect
	magnet	terror	squeeze	worship

Standardized Tests

The PPVT-III and the EVT were administered and scored as directed in the test manuals.

Definition

Each child responded to each of the 40 stimulus words with a verbal definition. To capture subtle differences in depth of word knowledge, scoring was based on amount of information included. Definitions received a 0 for no correct information; 1 for words that bore some meaningful relationship to the target but did not define it. Conventional but minimal definitions received a 2; definitions that included more than minimal accurate information received 3.

Word Association

Participants responded to each stimulus word with the first word that came to mind. We wished to capture subtle differences in knowledge but, unlike definitions, we could not do so by quantifying amount of information as all were limited to a single word. Instead scoring captured maturity of responses. Responses received 0 if they were "don't know" statements, repetitions with or without inflections (e.g., *chairs* in response to *chair*), or words that bore no semantic relationship to the target. The latter included perseverations and rhymes or other sound plays as these diminish by the end of the preschool years (Cronin 2002). Responses received 1 if they were anecdotal. Although meaningful for the child, these do not reveal knowledge of a conventional meaning. Syntactic devices such as particles (e.g., *up* in response to *soak*) received a 1. Responses that bore a thematic relationship to the target (e.g., *church* in response to *worship*) received a 2. Responses received 3 if they were paradigmatic (e.g., *like* in response to *enjoy*).

Reliability of Coding

For the sentence production and word association tasks, 15% of responses were randomly selected and coded independently by two research assistants blind to participants' group membership. Inter-rater point-to-point agreement on all dependent variables averaged at least 90%. Remaining responses were coded by a single assistant after agreement was established. Because of difficulty establishing reliability given a scale that quantified rather than classified responses, three research assistants, blind to group membership, independently scored every response in the definition task ($n = 4{,}960$). The average score was assigned if the three scores for a given item were in perfect agreement (e.g., $2 + 2 + 2 = 6$; $6/3 = 2$) (56% of all responses) or if the three scores differed by only a single point (e.g., $2 + 2 + 3 = 7$; $7/3 = 2.33$) (42% of all responses). If the three scores differed by more than a single point (e.g., 2, 3, 1) (2% of all responses), the assistants discussed the definition and came to a consensus.

Results

Sentence Production

Across participants, the number of analyzable sentences, out of a possible 40, ranged from 14 to 39 for the SM group, 28 to 38 for the SLI group, 32 to 40 for the ASDLI group, 29 to 40 for the ASD group, and 26 to 40 for the AM group. Given this variability, number of clauses per sentence was converted to a clause density value (number of clauses/number of analyzable sentences). A 5 (group) × 2 (word class) × 2 (meaning) ANCOVA by subject with clause density as the dependent variable and K-BIT2 raw scores as the covariate yielded no effect of K-BIT2 raw scores and no interactions between K-BIT2 raw scores and class or meaning. There was a main effect of group, $F(4.117) = 3.77$, $p = .006$, $\eta_p^2 = 0.11$. Planned comparisons revealed that the SLI and ASDLI groups produced sentences with lower clause density than the AM and ASD groups (p's $< .04$). The SLI, ASDLI, and SM groups did not differ (p's $> .46$) (SLI $M = 1.40$, SE $= 0.09$; ASLI $M = 1.50$, SE $= 0.10$; SM $M = 1.50$, SE $= 0.07$) nor did the ASD and AM groups ($p = .27$) (ASD $M = 1.81$, SE $= 0.08$; AM $M = 1.71$, SE $= 0.05$). There was a main effect of word class, $F(1.118) = 32.64$, $p < .0001$, $\eta_p^2 = .22$, such that verbs ($M = 1.70$, SE $= 0.04$) elicited more clauses than nouns ($M = 1.48$, SE $= 0.03$). Finally, there was a main effect of meaning, $F(1.118) = 19.06$, $p < .0001$, $\eta_p^2 = .14$, such that abstract words ($M = 1.67$, SE $= 0.04$) elicited more clauses per sentence than concrete words ($M = 1.51$, SE $= 0.04$).

The main effects of group and word class were qualified by an interaction, $F(4.118) = 2.75$, $p = .03$, $\eta_p^2 = .09$, such that only the AM group used significantly more clauses when formulating a sentence around a verb than a noun, $p < .0001$.

Lexical Semantic Profiles

Standardized Tests

A one-way ANCOVA with PPVT-III standard scores as the dependent variable and K-BIT2 raw scores as the covariate yielded a significant effect of K-BIT2 scores, $F(1.118) = 13.84$, $p = .0003$, $\eta_p^2 = .11$. There a main effect for group, $F(4.118) = 32.34$, $p < .0001$, $\eta_p^2 = .53$ (see Fig. 1a). The SLI and ASDLI scored lower than the ASD, AM, and SM groups (all p's $< .0002$). Despite these statistical differences, the standard scores of the SLI and ASDLI groups were not clinically significant, averaging 94 (SE $= 2.74$) and 93 (SE $= 2.96$), respectively. On the EVT, there was no effect of the K-BIT2 raw scores. There was a main effect of group, $F(4.117) = 31.38$, $p < .0001$, $\eta_p^2 = .52$, such that the SLI and ASDLI groups performed lower than all other groups (p's $< .0002$) (see Fig. 1b). Here, the SLI and ASDLI scores were also clinically significant averaging 74 (SE $= 3.39$) and 82 (SE $= 3.66$), respectively. The SLI and ASDLI groups did not differ on either test nor did the ASD, AM, or SM groups.

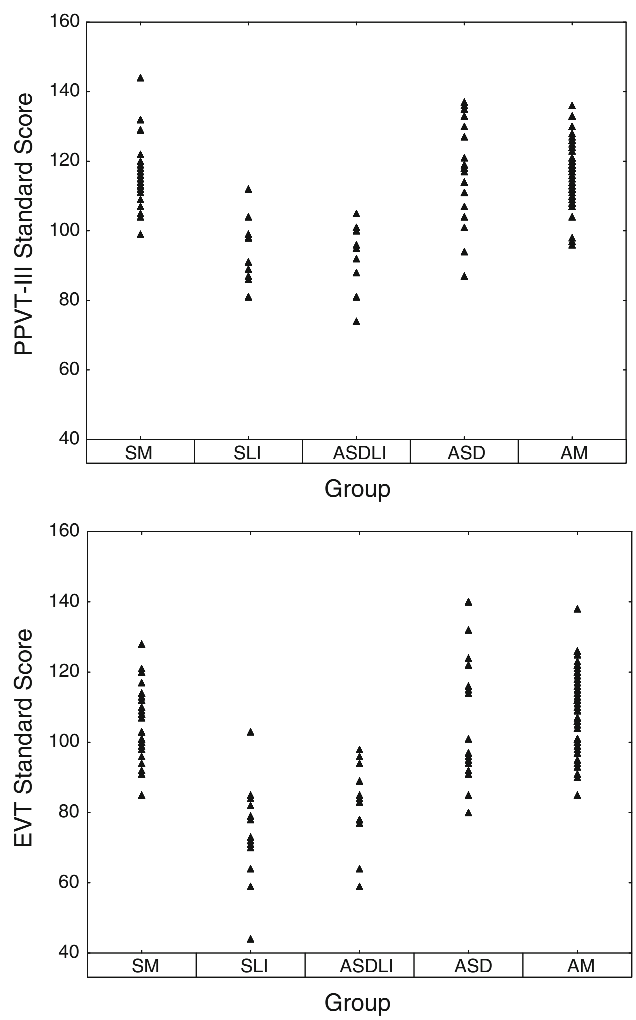

Fig. 1 PPVT-III and EVT profiles by group

Word Defining and Association

Data from two of 21 children in the ASD group were excluded as outliers because their responses were highly uncharacteristic of the ASD group. One child, the youngest at age 8;6, gave word associations that were sound based on 75% of all trials (e.g., *fact* elicited *attack*; *garage* elicited *massage*). The other, age 12;3, was uncooperative. His unrelated responses on the majority of word association trials (e.g., *helmet* elicited *rice*; *stretch* elicited *Capricorn*) were at odds with the knowledge he expressed on the definition task (e.g., *helmet*: "something to wear on your head;" *stretch*: "to pull something").

The definition profiles of the ASD and AM groups were superior to those of the SLI, ASDLI, and SM groups (Fig. 2a). The largest proportion of responses from the SLI, ASDLI, and SM groups fell from >0 to 1 whereas the largest proportion from the ASD and AM groups fell from >1 to 2. Few responses from the SM, SLI, and ASDLI groups merited the highest score; whereas few responses from the ASD and AM groups merited the lowest. However, 75% of the ASDLI participants and 100% of the SLI participants earned the highest score possible on at least one response.

Word association profiles appear in Fig. 2b. Scores of 2 were most common for all groups. The profiles of the ASD and AM groups again appeared superior to the others. The

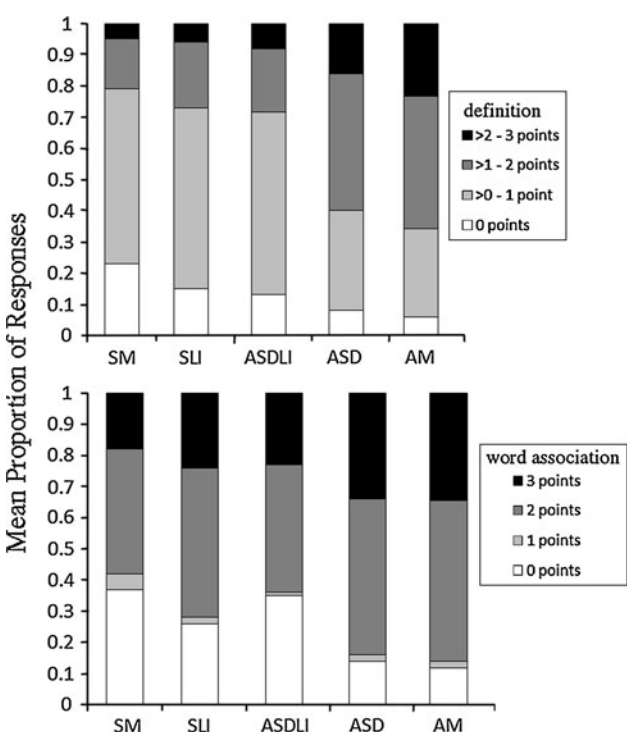

Fig. 2 Definition and word association response profiles by group

ASD and AM groups earned more scores of 3 than 0; in contrast, the SM, SLI, and ASDLI groups earned more scores of 0 than 3. However, 92% of the ASDLI participants and 100% of the SLI participants earned the highest score possible on at least one response.

Reasoning that both the definition and word association responses tapped depth of word knowledge, we planned to analyze them within a single MANCOVA. As a check on this reasoning, we first determined that the overall scores on these two tasks (with participant groups collapsed) were highly correlated, $r = .67$, $t = 10$, $df = 122$, $p < .0001$.

A 5 (group) × 2 (word class) × 2 (meaning) MANCOVA by subject yielded a significant interaction between K-BIT2 raw scores and word class, $F(1.116) = 5.64$, $p = .02$, $\eta_p^2 = .05$, thus violating the assumption of independence. We therefore abandoned the analysis of word class. Instead, we ran a 5 (group) × 2 (meaning) MANCOVA. Because we operationalized words with unobservable referents according to both word class (verb referents are less observable than noun referents) and meaning (abstract referents are less observable than concrete referents), analysis of meaning alone still allowed a test of the prediction that children with syntactic deficits would have particularly shallow representations of words with unobservable referents. In the revised MANCOVA there was a significant effect of the K-BIT2 covariate, $F(1.116) = 15.71$, $p = .0001$, $\eta_p^2 = 0.12$, but no interactions between the covariate and any independent variable.

As predicted, there was a main effect of group, $F(4.116) = 12.12, p < .00001, \eta_p^2 = .29$: The SLI, ASDLI, and SM groups performed similarly (SLI M = 1.37, SE = 0.08; ASDLI $M = 1.30$, SE = 0.08; SM $M = 1.12$, SE = 0.06) and all were significantly poorer than the ASD and AM groups (ASD $M = 1.80$, SE = .06; AM $M = 1.88$, SE = .04), p's $\leq .0007$. The ASD and AM groups did not differ from each other. There was the predicted effect of meaning, $F(1.116) = 25.85$, $p < .00001$, $\eta_p^2 = 0.18$, such that abstract words ($M = 1.23$, SE = 0.03) elicited lower scores than concrete words ($M = 1.74$. SE = 0.03). In addition, there was a main effect of task, $F(1.116) = 13.64$, $p = 0.0003$, $\eta_p^2 = 0.11$, with better performance on word association ($M = 1.74$, SE = .04) than defining ($M = 1.27$ SE = .03).

Main effects were qualified by an interaction between group and meaning, $F(4.116) = 2.64$, $p = .04$, $\eta_p^2 = 0.08$ (Fig. 3). The concrete-abstract gap was larger for the SLI group than the AM group ($p = .009$) and marginally larger for the SM group than the AM group as well ($p = .07$). The gap was also larger for the SLI and SM groups relative to the ASD group ($p = .005$ and $p = .04$, respectively). The ASD and AM groups did not differ in gap size ($p = .26$) nor did the SLI and SM groups ($p = .72$). The ASDLI group fell between the SLI and SM groups on the

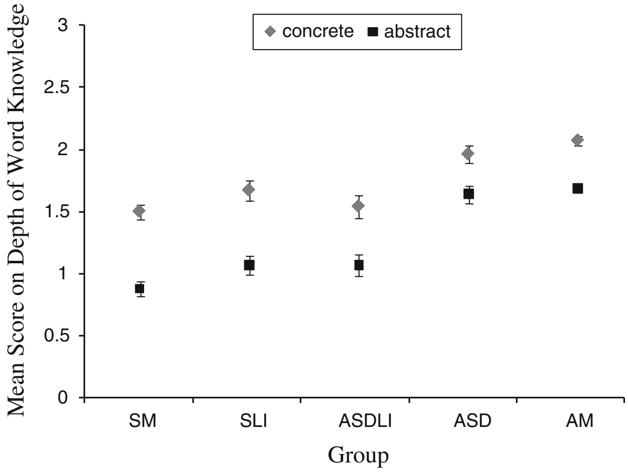

Fig. 3 Group × word meaning interaction

high end and the ASD and AM groups on the low end, thus differing from none, p's $\geq .16$.

Syntax and Depth of Lexical Semantics

We further explored the syntax-lexicon relationship by treating syntactic ability as a continuous variable. To maximize power, we formed two groups: those with autism (ASD + ASDLI, $n = 31$) and those without (SLI + AM, $n = 65$). Data from the younger SM participants were excluded. There was a positive correlation between syntax and depth for both those with autism ($r = .54$, $r^2 = .29$, $p = .001$) and those without ($r = .71$, $r^2 = .50$, $p < .001$) (Fig. 4).

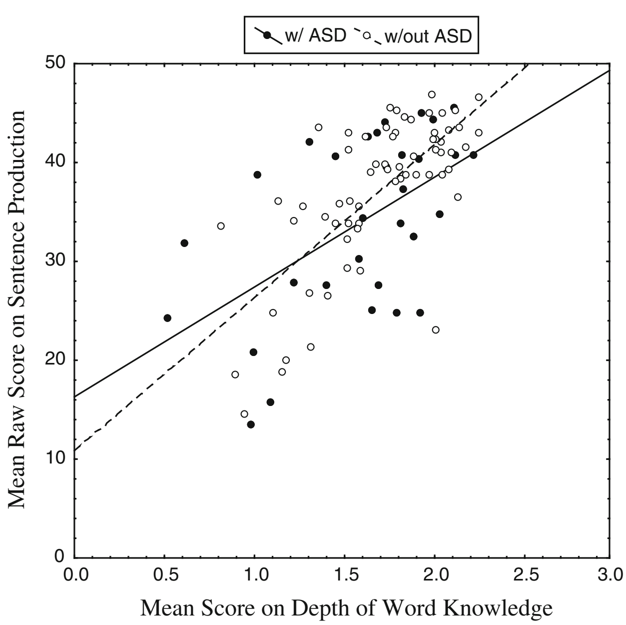

Fig. 4 Relationship between syntactic ability and depth of word knowledge for children with and without autism

Finally, we related the extent of social-pragmatic disability to performance in the group affected by autism. Social-pragmatic disability was estimated by raw scores on the ADOS Communication + Social Interaction algorithm. There was a significant negative correlation of −.50 between scores on the ADOS and depth of word knowledge, $r^2 = .26$, $p = .003$. On the ADOS, higher scores represent more severe autistic behavior; therefore, the children with more social-pragmatic involvement performed more poorly on measures of depth than did children with less involvement. To determine the relative predictive values of CELF-syntax and ADOS-Communication + Social Interaction scores we entered both into a forward step-wise regression model. On step 1, syntax accounted for 29% of the variance, $p = .002$; on step 2, the communication + social interaction scores accounted for an additional 11%, $p = .03$.

Discussion

Our purpose was to inform the debate on the similarities and differences of the ASDLI -SLI phenotypes by evaluating syntactic ability, depth of lexical semantics, and the link between these domains in affected children.

We confirmed that children selected because of poor performance on a standardized test of syntax, those classified as ASDLI or SLI, also exhibited weak syntactic ability when asked to build sentences with the stimulus words used in this study. We also found these groups to score significantly lower than age-mates, whether normally developing or with ASD, on standardized measures of vocabulary and on two probes of depth of lexical semantics, word definitions and word associations. In contrast, children with ASD who, by definition, had social-pragmatic deficits but no syntactic deficits, had similarly rich word knowledge as their unaffected age-mates. This was true even though the stimulus words included mentalistic (e.g., *believe*, *consider*) and emotion-laden (e.g., *love*, *worship*) meanings. Moreover, the children with social-pragmatic deficits plus syntactic deficits (ASDLI) performed similarly to their peers with syntactic deficits only (SLI). The clinical and theoretical contributions of these findings are explored below.

Syntactic Profiles

The ASDLI and SLI groups made sentences with fewer clauses than their AM or ASD peers; instead their sentences were similar to those of their younger SM peers. Abstract words elicited more clauses than concrete words. This pattern likely reflects argument structure differences. The abstract verbs, in particular, permit sentential complements (e.g., I *believed/decided/complained/suspected* that he drove her crazy) whereas the concrete verbs do not. This pattern held for all groups, even those with ASDLI and SLI. Therefore, although their sentences were simpler overall than their peers', they did rise to the challenge of increasing complexity in response to abstract words.

There are abundant descriptions of the expressive syntax of children with SLI (see Leonard, 1998 for a review). Consistent with our own findings, these generally reveal shorter and less sophisticated sentence structures on the part of children with SLI as compared to unaffected age-mates. Comparable descriptions of children with ASD are less abundant. One recent exception is Eigsti et al. (2007) who compared the morphosyntactic productions of verbal preschoolers with ASD (unselected for presence or absence of syntactic deficits) to those of younger unaffected peers matched on nonverbal IQ and receptive vocabulary. Consistent with our own findings, they found syntactic deficits characterized by reduced sentence length and complexity among the participants with ASD. However, our findings did differ from those of Eigsti in one way: syntactic deficits characterized their entire sample. In our sample, we have one group with clear syntactic deficits and one without. Of course we selected them because of this very difference in their profiles.

Why would it be that all of the children in Eigsti et al. were of the ASDLI type? Three possibilities include chance (by chance they missed children of the ASD type and recruited those with ASDLI only), a developmental difference (their sample was considerably younger than ours), or a task difference. The task we used to elicit sentences was highly decontextualized; therefore, pragmatic load on appropriate sentence formulation was low. Their task involved a naturalistic context where discourse constraints were at play. If chance in sampling is the explanation then a replication of Eigsti et al. might well reveal that some children present with ASDLI but others present with ASD and no concomitant syntactic deficit. If development is the explanation then a longitudinal study that follows children from preschool to high school would demonstrate that all verbal children on the autism spectrum are better described as ASDLI in their younger years but that some are better described as ASD when they grow older (see Williams et al. 2008 for this hypothesis). If task demand is at play then our own ASD cohort would demonstrate syntactic limitations when placed in discourse contexts that require pragmatic and syntactic sophistication. In short, there are many remaining questions to be answered about the relative prevalence of ASDLI versus ASD, the developmental course of ASDLI, and the contexts that best elicit limitations associated with ASDLI.

Lexical Profiles of Children with ASDLI or SLI

Although children with syntactic deficits scored statistically lower than their unaffected peers on the PPVT-III, only 2 of 13 children with ASDLI and 1 of 14 children with SLI scored more poorly than one standard deviation below the mean, arguably a cutoff that merits clinical concern. In other words, the PPVT-III was not sensitive to the deficits that characterized the ASDLI and SLI groups. The PPVT-III is not recommended as a tool for identification of SLI (Gray et al. 1999) and it appears that its use in identifying ASDLI may be limited as well. In contrast, the EVT (second edition) was more sensitive, with a majority of children in the ASDLI and SLI groups scoring more than one standard deviation below the mean. Gray et al. (1999) did not find this to be the case when they administered the EVT (first edition) to preschoolers with SLI; in that study most children with SLI scored within one standard deviation of the mean. However, at the preschool level, the EVT requires picture naming responses. At the school age level, the EVT requires synonym naming, thus, word-to-word knowledge is tapped.

Definitions and word associations also require word-to-word knowledge and, because we measured these on a graded rather than binary scale, they are, arguably, sensitive measures of depth of word knowledge. When defining, the ASDLI, SLI, and SM groups most often provided partially correct but incomplete definitions, revealing some knowledge of those targets. In contrast, the ASD and AM groups most often provided a complete, if somewhat minimal, definition, revealing deeper knowledge. Of course, one might be tempted to attribute these results to syntactic demands of the task. To define words, the participants had to formulate sentences and, of course, the members of the ASDLI and SLI groups were selected precisely because they have difficulty formulating sentences. However, that 75% of the ASDLI group and 100% of the SLI group earned the highest possible score on one or more items reduces this concern.

The word association task should further satisfy the skeptic because it required single word responses only. On the word association task, all groups responded most often with thematic relationships such as "sit" in response to "chair." Although clearly relevant, these are less mature than paradigmatic relationships such as "table" in response to "chair." The SM, SLI, and ASDLI groups gave fewer paradigmatic responses than the ASD and AM groups, again revealing sparser knowledge on the part of the former groups and deeper, more mature knowledge on the part of the latter.

All groups demonstrated sparser knowledge of abstract words than concrete words; however, the concrete-abstract gap was particularly large for children with SLI and their

SM peers. This was predicted to be the case because the ability to make use of syntactic context is especially important when learning the meanings of abstract words. Children with SLI, by virtue of their syntactic deficits, and children in the SM group, by virtue of their fewer years of exposure to syntactic constructions and abstract words, should be at a disadvantage in this regard.

What was more curious was that the ASDLI group, who should be equally disadvantaged, did not demonstrate a particularly large concrete-abstract gap; their gap was not different in size to that of the AM or ASD groups. Likewise, Eskes et al. (1990) reported no differences in size of the concrete-abstract gaps that characterized comprehension performance of a group of children with ASDLI and their unaffected reading-matches. We speculate that the diminished concrete-abstract gap reflects clinical intervention effects. Specifically, 12 of the 20 abstract words (but none of the concrete words) conveyed emotion (e.g., *loyalty*), mental activity (e.g., *believe*) or communication (e.g., *advise*). Such words pose difficulty for individuals with ASD (Hobson and Lee 1989) and hence are likely intervention targets. Another related possibility is that individuals with ASD learn decontextualized meanings for abstract words via rote mechanisms (Capps et al. 1992).

With the exception of the size of the abstract-concrete gap, the profiles of the SLI and ASDLI groups were highly similar. Both groups demonstrated incomplete knowledge of word meanings and immature appreciation of word-to-word relationships. We readily admit that our tasks measure extant knowledge only and at a relatively late point in childhood, ages 9-to-14 years. We cannot draw conclusions about the extent to which these groups share etiology or developmental course as similar outcomes can be achieved by disparate developmental trajectories (Karmiloff-Smith 1998).

Relationship between Syntax and Lexical Semantic Knowledge

With syntactic ability treated as a continuous variable, we found significant positive correlations between expressive syntax as measured by the CELF4 and depth as measured by two expressive measures, the definition and word association tasks, for those with autism and those without. Similarly, within a group of participants affected by autism that was more wide ranging in age (4-to-14 years) and nonverbal IQ (49–153) than ours, Condouris et al. (2003) reported a significant positive correlation between sentence structure on the CELF-P/CELF3 and lexical ability as measured by the PPVT-III and the EVT. We conclude that the relationship between syntax and the lexicon that characterizes early normal child language development (Fenson et al. 1994) characterizes later and impaired child language development as well.

Lexical Semantic Knowledge among Children with ASD

A primary clinical contribution of this study is the demonstration that deficits in lexical depth are characteristic of developmental language impairment but not autism *per se*. Let us be clear: Many children on the spectrum do have lexical semantic deficits. In fact Groen and colleagues (2008) refer to “difficulties in both understanding and expressing the lexicon …[as] the most widely recognized linguistic impairments in autism” (p. 1418). However, when autism is isolated from mental retardation and syntactic deficits, as in the current ASD group, performance is age appropriate. Our results, while limited to the expressive domain, are consistent with those of Norbury (2005) and Brock et al. (2008) who found children with ASD but without concomitant syntactic deficits to have age-appropriate comprehension of word meanings. Autism, and its characteristic deficits in cognition and social-pragmatic functioning, do not necessarily lead to suboptimal development of the lexicon.

That said, the current data do not rule out a role for social-pragmatics in the establishment of lexical meanings. Although we did not find sparse word knowledge among children with ASD via group comparisons, the degree of impairment on the social-communicative subtests of the ADOS was correlated with sparseness of lexical semantics. Children with ASD often fail to make use of cues provided by their social partners during word learning (Baldwin 2000). Such failures can lead to erroneous inferences about new word meanings thus impeding or slowing the establishment of accurate and rich lexical semantics. These failures may be reflected in the ADOS-lexical semantics correlation.

Conclusions

School-age children with ASD do not necessarily have deficits in syntax or lexical semantics. Like children with SLI, children with ASD who *do* have syntactic deficits (i.e., those with ASDLI) tended to have sparse lexical semantics as well. Moreover, when syntactic ability was treated as a continuous variable and groups were defined based solely on presence or absence of ASD, a positive relationship between syntactic and lexical abilities was evident in both groups. Among those with ASD, syntactic ability was a stronger predictor of lexical-semantic depth than degree of social-pragmatic impairment.

The SLI and ASDLI groups were not identical. The children with SLI had a larger performance gap between abstract and concrete words than their unaffected age-mates; the children with ASDLI did not. Given the multi-determined nature of word learning, together with very different levels of social-pragmatic abilities that the two groups bring to the task, it would be surprising to find that their lexical profiles were identical. Nevertheless, the ASDLI and SLI groups presented with similar limitations in depth of lexical semantics. Both demonstrated partial knowledge of word meaning and immature knowledge of word-to-word relationships. This behavioral overlap speaks to the robustness of the syntax-lexicon interface, illustrates a similarity in the ASDLI and SLI phenotypes, and points to common language intervention goals for affected children.

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Appendix

Sentence Formulation Procedures

Task Instructions, Models, and Prompts

I'm going to say a word and your job is to put it in a sentence. Like if I said "dog" you might say, "The spotted dog hunted cats in the neighborhood," or if I said "memorize" you could say, "The student memorized the answers on the test." Do you have the idea of what to do? OK, the first word is…

Examiner's Note: Prompt for the child to think of a different type of the word if they respond with the wrong word class.

Scoring Guidelines with Examples

Sentences were scored according to number of clauses. A clause was defined by the occurrence of a main verb. Each sentence was analyzed if it included a verb and the target word used as the targeted word class.

Example sentence in response to *purpose* with verbs underlined:

"The mom that <u>picks up</u> (her) the kids <u>says</u> "What'<u>s</u> the *purpose* of <u>running</u> away from school without <u>getting</u> your food"? = 5 clauses

Definition Procedures

Task Instructions, Models, and Prompts

I'm going to say some words. Your job is to tell me what each word means. For example, if I said "dog" you might say, "it's an animal, it has fur and a tail and four legs, and for example a poodle is a dog." If I said "memorize" you might say, "when you memorize something you try to remember it forever, like you might memorize your phone number." You have the idea, right? OK, your first word is….. (Note: Prompt for the child to think of a different type of the word if they respond to the wrong word class.)

Scoring Guidelines with Examples

0- No correct information.

<u>Worship:</u> It's when you sell something, like hand-me-downs.
<u>Origin</u>: The state "origin".

1- Information is at least partially correct but definition is not conventional.

<u>Believe:</u> Would faith be kinda like believing? You can believe in different religions, and different kinds of stuff like deodorant.
<u>Mystery:</u> Like the mystery of the disappearing sock, like my disappearing sock that I found in my sock drawer under my underwear.

2- Information is correct and conventional but minimal.

<u>Stretch:</u> To make longer.
<u>Chair:</u> Chairs are things that people sit on.

3- Information is correct, conventional, and well elaborated.

<u>Worship:</u> Praise something, like the Lord, or football, or statues.
<u>Stretch:</u> Pulling something so that it expands; you can stretch a rubber band.

Word Association Procedures

Task Instructions, Models, and Prompts

I'm going to say some words. As soon as I say each word, I want you to say the first word you think of, and your answer can only be one word. For example, what is the first word you think of when I say "dog" (praise answer) Yes, you could say "bone, or barks, or cat," all of those things come to mind when we hear dog, right? What about "memorize"? You could say "answer, hard, or test," because all of those things come to mind when we hear memorize. Do you have the idea of what to do? OK, the first word is… (Note: If the child responds with rhymes, direct him/her away, "In this activity, we aren't interested in rhyming so you don't need to make rhymes," and if the child gives the same word or near inflection prompt for another word. Also, prompt for one word responses and responses to the correct word class.)

Scoring Guidelines with Examples

0- No discernable relationship.

chair: toy
consider: done

1- The relationship is minimal in that it is idiosyncratic, syntactic, or derivational.

love: you
health: healthy

2- The relationship is thematic.

table: dinner
love: family

3- The relationship is paradigmatic-taxonomic.

coin: money
love: hate

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