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Mutual exclusivity in autism spectrum disorders: Testing the pragmatic hypothesis

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ABSTRACT

While there is ample evidence that children treat words as mutually exclusive, the cognitive basis of this bias is widely debated. We focus on the distinction between pragmatic and lexical constraints accounts. High-functioning children with autism spectrum disorders (ASD) offer a unique perspective on this debate, as they acquire substantial vocabularies despite impoverished social-pragmatic skills. We tested children and adolescents with ASD in a paradigm examining mutual exclusivity for words and facts. Words were interpreted contrastively more often than facts. Word performance was associated with vocabulary size; fact performance was associated with social-communication skills. Thus mutual exclusivity does not appear to be driven by pragmatics, suggesting that it is either a lexical constraint or a reflection of domain-general learning processes.

1. Introduction

In *Categorization and Naming in Children* (1989), Ellen Markman presented a set of questions and phenomena that have fueled research on word learning for 20 years. Early cognitive accounts of language acquisition focused primarily on syntax (see the papers in Slobin (1985) for examples and Clark (1973) for a discussion), perhaps because many theorists assumed that word learning could be explained by simple associations between word forms and referents. This assumption was challenged by researchers who pointed out that the midcentury philosophical critiques of empiricism (Goodman, 1966; Quine, 1960) were transparently applicable to the problem of lexical acquisition; that is, the input itself can never logically disambiguate the meaning of a word (see e.g., Landau, Smith, & Jones, 1988; Macnamara, 1982; Markman & Hutchinson, 1984). The experiments that followed demonstrated that young children do not learn words through brute force associative learning; instead they approach the task with a set of constraints that help guide them to the correct meaning, minimizing the need for extensive observation. For example, children preferentially map labels to whole objects, rather than their parts or other qualities, and they extend these labels to other members of the same taxonomic category, rather than to thematically-associated objects (Markman, 1990; Markman & Hutchinson, 1984). In the case of novel artifacts, these taxonomic categories are typically inferred on the basis of the object's shape or function, rather than its color, texture, or location (Kemler Nelson, Frankenfield, Morris, & Blaire, 2000; Landau et al., 1988).

The discovery of these constraints on word learning immediately raised questions about their origins and their scope. Are these particular constraints present at the onset of word learning or do they emerge as the product of prior word learning (see e.g., Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002)? Are these constraints specific to word learning or are they side effects

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of more general constraints on conceptualization or communication (see e.g., Bloom, 2000; Clark, 1990)? This paper focuses on two theories about the scope and origins of a constraint that Markman dubbed "mutual exclusivity" (Markman & Wachtel, 1988).

Mutual exclusivity, in Markman's theory, is the learner's bias to assume that category labels apply to mutually exclusive sets of objects and thus each object has only one category label. This bias is evidenced by children's tendency to avoid a second label for a single referent. For example, imagine a child sitting in the kitchen with her mother. Two objects previously unknown to the child, a pepper and a bok choy, are in front of her on the counter. The mother holds the pepper up to her child and states, "What a pretty pepper!" Given the social cues available in this context, the child will presumably link this label, correctly, to the pepper. Imagine next that the mother puts the pepper back down on the counter and says, "Bok choy is delicious!" while glancing in the general direction of both vegetables. Mutual exclusivity, and the research that supports it, suggests that the child will be able to infer that the new label ("bok choy") applies to the unlabeled object (the bok choy), despite the ambiguous social cues that accompany this utterance.

Mutual exclusivity is a robust phenomenon. It has been observed in a variety of experimental paradigms, in children as young as 12 months of age (Clark, 1988; Diesendruck & Markson, 2001; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Graham, Poulin-Dubois, & Baker, 1998; Halberda, 2003, 2006; Littschwager & Markman, 1994; Markman, Wasow, & Hansen, 2003; Scofield & Behrend, 2007; Xu, Cote, & Baker, 2005). The phenomenon is present in diverse populations, including bilingual children (Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005), deaf and hard-of-hearing children (Lederberg, Prezbindowski, & Spencer, 2000), children with William's Syndrome (Stevens & Karmiloff-Smith, 1997), and children with autism (Preissler & Carey, 2005). But while there is ample evidence that children treat words as mutually exclusive, the cognitive basis of this bias is widely debated (Bloom, 2000; Clark, 1990; Diesendruck & Markson, 2001; Markman et al., 2003; Merriman & Bowman, 1989; Mervis, Golinkoff, & Bertrand, 1994).

Two types of paradigms have been used to demonstrate mutual exclusivity. These subtly different paradigms support very different inferences about the nature of the constraint.

Novelty paradigms (Graham et al., 1998; Halberda, 2003; Markman & Wachtel, 1988; Preissler & Carey, 2005) present participants with one familiar object (e.g., a ball) and one novel object, and then ask them to produce an object based on a novel label (e.g., "give me the wug"). Participants typically select the novel object in this context. Although critical to the early observations of mutual exclusivity, novelty paradigms are limited in that they confound novelty with exclusivity. That is, the only novel object is also the only unlabeled object, so when children select the novel object, we cannot be certain that they are selecting this object because it is unlabeled (and thus treating words exclusively), or on the basis of its novelty alone, perhaps reflecting a simple preference for new things, or a tendency to match novelty-to-novelty.

Exclusivity paradigms (Diesendruck & Markson, 2001; Scofield & Behrend, 2007; Xu et al., 2005) remove the novelty confound by presenting children with *two* novel objects, labeling one with a novel label (e.g., "this is a jop"), and then asking for an object using a second novel label (e.g., "give me the wug"). Since both objects are novel, the possibility that children are solving this task by simply matching novelty-to-novelty can be ruled out, and we can conclude that children are selecting the target object because it is unlabeled. Exclusivity paradigms thus provide clear evidence that the child is making the inference that novel words go with unlabeled objects.

Several theories have been put forward to explain the robust mutual exclusivity bias; the two theories that are most relevant for the present experiment are the pragmatic account and the lexical constraints account. The *pragmatic account* proposes that mutual exclusivity is just one manifestation of broader social communicative competence (Bloom, 2000; Clark, 1990; Diesendruck & Markson, 2001; Woodward & Markman, 1998). Infants are able to make inferences about adults' intentions including their communicative or referential intentions (Akhtar, Carpenter, & Tomasello, 1996; Carpenter, Akhtar, & Tomasello, 1998; Olineck & Poulin-Dubois, 2005; Woodward, 1998). According to the pragmatic hypothesis, this ability to infer referential intentions is the basis of exclusivity effects. For example, Clark (1988,1990) proposes that listeners (infants and adults) are guided by the principle of contrast, which posits that different linguistic forms arise from different communicative intentions. Specifically in the case of referential terms (noun phrases or descriptions), listeners assume that different forms must pick out different referents. This can be seen as an implicature arising from the Gricean maxim of manner which states that speakers will state things in the simplest and least ambiguous manner possible (1975). If an object already has a mutually known label, failure to use this label implies that the speaker must not intend to refer to that object. To extend the earlier example, on the pragmatic hypothesis, the child who hears "bok choy" reasons (unconsciously) as follows: "if mom had wanted to refer to that object [the pepper] she would have used the same description as before ('pepper'), but she used a different description, so she must be referring to something else and this [the bok choy] is the only likely candidate."

In contrast to the pragmatic account, the *lexical constraints account* proposes that early in word learning, children assume that words (or at least object labels) refer to mutually exclusive categories, such that individual objects are assigned one, and only one, object label (Markman & Wachtel, 1988). Based on this assumption, children reject objects with known names as possible referents for novel words, whittling down the number of possible referents. When one unlabeled object is present during a labeling act with a novel word, then the whole object constraint (Markman, 1990) will lead children to assume that the novel label applies to this object. On this hypothesis, both constraints are domain-specific mechanisms specific to word learning (Markman, 1992; see also Merriman & Bowman, 1989, Golinkoff, Mervis, & Hirsh-Pasek, 1994). In our earlier example, a child using the mutual exclusivity

constraint would (unconsciously) reason as follows: "That object [the pepper] is called a 'pepper', so it can't be called 'bok choy.' But this object [the bok choy] doesn't have another name, so it must be the bok choy."

A third type of theory, the domain-general account, attributes the phenomenon of mutual exclusivity to domain-general learning processes. On such accounts, word learning constraints are either a direct reflection of the structure of domain-general learning mechanisms or are the result of applying these learning mechanisms to input which has an underlying structure that gives rise to the relevant constraint (Regier, 2005; Smith et al., 2002).[1] For example, Regier (2003) proposes that mutual exclusivity arises from general mechanisms of competition in a connectionist network. As a word becomes more associated with one referent, the probability that the same word will be used with another referent declines sharply. Similarly, Frank and colleagues (2009) were able to simulate mutual exclusivity effects in a Bayesian model of word learning and intention reading which contained no initial structure or parameters that were specifically linguistic in nature. These domain-general models present a compelling challenge for the lexical constraints account, which we explore further in the discussion section. However, for now we put the domain-general theory aside. The current study was specifically designed to distinguish between pragmatic and lexical constraints accounts, and thus it does not provide direct evidence for or against domain-general models. However, our data does have implications for theories of this kind, which will be laid out in the general discussion.[2]

The pragmatic account and the lexical constraints account differ in their scope: although lexical constraints apply only to words, the ability to infer speakers' referential intent should apply to all speech acts, including descriptions of objects. Studies of conversational communication have demonstrated that speakers typically settle on a single form for a given referent and then use it throughout their discourse. Initially these descriptions may be long and variable, but they become shorter and more predictable as interlocutors settle on a common referential understanding (Krauss & Weinheimer, 1966). Thus listeners expect speakers to refer to the same object consistently, because this is what they typically do.

Diesendruck and Markson (2001) tested the prediction that exclusivity applies to diverse speech acts by comparing children's tendency to treat words contrastively with their tendency to treat facts contrastively. A standard exclusivity task was used to test exclusivity for words (label condition) and a parallel task was constructed to test exclusivity for facts (fact condition). Specifically, one of two novel objects was linked to a novel *fact* ("my sister gave me this") and children were then asked to produce the referent of a second novel fact ("Can you give me the one my dog likes to play with?"). Diesendruck and Markson reasoned that if mutual exclusivity was subserved by a lexical constraint, then children should treat words as exclusive, but not facts. In contrast, if mutual exclusivity was the result of a broader social pragmatic constraint, then both words and facts should be treated as exclusive. They found that 3-year-olds performed similarly in the label and fact conditions, treating both forms as exclusive. Thus they concluded that the same social pragmatic inference accounted for performance in both conditions. This is spelled out as Hypothesis A, below. But note that these results are logically compatible with the possibility that exclusivity for words and facts are subserved by different mechanisms that just happen to be equally robust in 3-year-old children. This is spelled out as Hypothesis B.

Hypothesis A A single ability, social pragmatics, underlies children's tendencies to treat words and facts contrastively. This tendency is driven by children's expectation that speakers will refer to a single object consistently. This expectation alone accounts for the mutual exclusivity bias (Diesendruck & Markson, 2001).

Hypothesis B. Different mechanisms account for exclusivity in words and facts. The tendency to treat words as mutually exclusive is the result of lexical constraint, and thus specific to word learning. However, children also have access to social-pragmatic reasoning processes that may lead them to treat facts contrastively as well.

In the absence of further data, Hypothesis A should be favored on the basis of parsimony. Why posit two mechanisms when one will do? However, given the pervasiveness of exclusivity for words, it is critical to determine whether exclusivity for facts is present in the same range of tasks and populations. Any lack of parallelism in the development or prevalence of exclusivity for words and other speech acts would favor Hypothesis B.

Preliminary support for Hypothesis B comes from research on mutual exclusivity at earlier stages of development. Scofield and Behrend (2007) found that 2-year-olds treat words as exclusive but not facts, suggesting that separate mechanisms may underlie performance in the two conditions (see also Markson, 2005). This data, however, is difficult to interpret due to the young age of the participants. To use the principle of contrast, the child must recognize that the speaker is producing two different referential forms. In the case of the words this simply involves representing the phonological forms of the two labels and comparing them ("zav" is not "koba"). In contrast, the facts are phrases that are longer in length and have internal syntactic and semantic structure. Furthermore, in this task, the syntactic form of the facts shifts from the exposure phrase in which a declarative form is used ("My uncle gave me this") to the test phase, in which

[1] Constraints were initially motivated by the need to limit the possible hypotheses that the child considered to avoid the logical problem of induction (Goodman, 1966; Quine, 1960). Consequently, theories that posit that constraints are learned via association would seem to risk circularity. In practice they avoid it by positing that word meanings are drawn from a finite hypothesis space. In other words, the initial, strong constraints in such models are built into the input representation.

[2] While the pragmatic account and the lexical constraints account offer competing hypotheses about of the scope of exclusivity, some versions of the domain-general account are, in principle, compatible with both of these proposals. A domain-general mechanism could presumably be used to acquire either pragmatic bias to treat different referential acts as contrastive or a lexical bias to treat words as mutually exclusive.

a definite description is produced ("The one my cat stepped on"). Very young children, with limited linguistic abilities, may have difficulty representing these facts, holding them in memory, or comparing them to determine whether a contrasting form was used (Markson, 2005). Even if they succeed at all of these tasks, they may have fewer resources left for making inferences about the experimenter's referential intent. Thus, for 2-year-olds, performance on the label condition may be superior to performance on the fact condition only because the labels are simpler. Thus additional work is needed to understand whether the contrastive interpretation of words and the contrastive interpretation of facts are driven by the same cognitive mechanisms, as the pragmatic account proposes.

To tease apart Hypotheses A and B, above, we have chosen to look at mutual exclusivity in a group of children and adolescents who show impoverished social-pragmatic reasoning, specifically, individuals with autism spectrum disorders (ASD). ASD is a neurodevelopmental disorder characterized by profound deficits in social interaction and communication, and by repetitive and restricted behaviors and interests (APA, 2000). Individuals with ASD are notably impaired in their ability to infer speakers' referential intent (Baron-Cohen, Leslie, & Frith, 1986; Phillips, Baron-Cohen, & Rutter, 1998; Sabbagh, 1999). Within the ASD population, there is great heterogeneity in terms of linguistic abilities; many never go on to develop fluent speech, while others demonstrate superior verbal skills (Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg, 2006). Syntactic and morphological development are delayed (Eigsti, Bennetto, & Dadlani, 2007), even into early adolescence (Eigsti & Bennetto, 2009). Even for those who develop average and above average language skills, pragmatic abilities are universally impaired (Tager-Flusberg, Paul, & Lord, 2005). In contrast, vocabulary development tends to be an area of relative strength (Jarrold, Boucher, & Russell, 1997; Kjelgaard & Tager-Flusberg, 2001). Although most linguistic and communicative skills for individuals with ASD (such as conversational discourse and nonverbal communication) tend to fall below what would be expected given their overall cognitive levels, vocabulary size is often commensurate with overall cognitive capacities. The fact that many children with ASD are able to build substantial vocabularies despite impoverished social-pragmatic skills provides a preliminary suggestion that pragmatic skills may not be a necessary condition for word learning and vocabulary development. With respect to mutual exclusivity this suggests two possibilities: (1) mutual exclusivity is a pragmatic skill but highly verbal children with ASD are able to use other cues and strategies to compensate for the absence of mutual exclusivity (consistent with the pragmatic hypothesis) or (2) mutual exclusivity is fully present in verbal children with ASD suggesting that it does not depend on the kind of pragmatic skills that are impaired in this population (consistent with the lexical constraints hypothesis).

Because children with ASD show such profound deficits in social interaction, studies of word learning in ASD have primarily focused on how these children's social deficits interfere with their word learning. Children with ASD are notably impaired in their ability to initiate and follow joint attention, a deficit associated with extensive delays in early language acquisition (Bono, Daley, & Sigman, 2004; Loveland & Landry, 1986; Mundy, Sigman, & Kasari, 1990). The abilities of children with ASD to follow a speaker's direction of gaze (Baron-Cohen, Baldwin, & Crowson, 1997) and focus of attention (McDuffie, Yoder, & Stone, 2006) have been shown to be significantly related to their ability to correctly apply novel labels to novel objects. The ability to interpret speakers' referential cues appears to be more of a rate-limiting step to word learning for children with ASD than for children with typical development (TD), presumably because their deficits in this area present roadblocks for acquisition (Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007). Despite these limitations, the majority of children with ASD (>80%) are able to learn words, particularly nouns, by middle childhood (Lord, Risi, & Pickles, 2004). In fact, children with ASD have been shown to apply some of the same constraints that TD children do, such as interpreting novel words as referring to objects rather than actions (Swensen, Kelley, Fein, & Naigles, 2007).

To our knowledge, only one published study has examined the mutual exclusivity bias in children with ASD. Preissler and Carey (2005) studied mutual exclusivity in 20 5- to 9-year-old children with autism. Their sample had a mean receptive vocabulary age of 23 months. These children were impaired in their ability to use speakers' direction of gaze as a strategy for making word-object mappings, suggesting that they did not use speakers' referential intent to guide word learning. The same group of children, however, successfully completed a *novelty* task; that is, when presented with a familiar object and an unfamiliar object and asked to show the experimenter a "blicket," they reliably chose the unfamiliar object. The low verbal level of the participants likely motivated the simpler paradigm that was used in this study. The novelty task consisted of only two trials: one trial included a familiar drawing and a novel drawing as stimuli, and the second trial used a familiar object and a novel object. The familiar things were always natural kinds (apple and duck) and the novel things were complex artifacts (air pump and noisemaker). Thus, the conclusions that can be drawn from this study are limited by the presence of a novelty confound. We cannot be certain that the phenomenon they observed is really about *exclusivity*. That is, the children in their study could simply have been matching novelty-to-novelty, or showing a preference for novel, mechanical objects if the task was unclear, a possibility that is even more likely for children with ASD, who often show a distinct preference for mechanical objects (South, Ozonoff, & McMahon, 2005). To conclude that children are truly using an exclusivity strategy, an exclusivity paradigm must be used.

In the current study, we use Diesendruck and Markson's (2001) exclusivity paradigm to compare children's use of exclusivity for words with their use of exclusivity for facts. Our goal was to answer three questions. First, are individuals with ASD truly using exclusivity in word learning despite their pragmatic impairments? If so, this suggests that the cognitive basis of exclusivity is not tightly tied to social-pragmatic skills. Second, do individuals with ASD apply exclusivity to other referential acts, such as factual

descriptions? This provides an index of children's ability to use contrasting forms to make inferences about the referential intent of others. Third, what are the correlates of using exclusivity for words and for facts, in both ASD and TD? If exclusivity for words and exclusivity for facts are driven by distinct underlying mechanisms, then it is likely that they will be associated with different traits or abilities. Specifically, exclusivity for words may relate to vocabulary skills, and exclusivity for facts may relate to social-pragmatic skills. Individuals with ASD provide advantages for studying typical developmental processes such as word learning (Cicchetti & Rogosch, 1996; Marcus & Rabagliati, 2006), in part because they introduce more variability, within and across domains, than is found in typical populations. We take advantage of this variability to explore additional predictions of pragmatic and lexical constraints accounts.

In contrast to Preissler and Carey (2005), we limited our sample to participants who had average or above average language abilities for their age. As we noted earlier, comprehension of the facts may be taxing for children with limited linguistic abilities, so we wanted to ensure that participants in this study had verbal skills that were at least as well developed as the 3- to 4-year-old children who succeed in this task (Diesendruck & Markson, 2001; Scofield & Behrend, 2007). In addition, the exclusivity task itself is demanding, involving two novel linguistic forms and two novel objects; thus, lower functioning children might fail for uninteresting reasons.

We compared our participants with ASD to TD controls who were matched on age and vocabulary ability. Two different age groups were tested (children and adolescents) to explore whether exclusivity for words and facts changes over development. Previous studies have demonstrated that word learning strategies change over development (Halberda, in preparation; Merriman & Bowman, 1989; Nazzi & Bertoncini, 2003), but this work has focused on development in the first 4 years of life. On the pragmatic hypothesis, exclusivity for words and facts should remain yoked across the lifespan. Finally, for a subset of the participants we conducted a control task to assess memory and attention for novel words and facts. Even high-functioning individuals with ASD often have deficits in attention (Landry & Bryson, 2004; Townsend, Harris, & Courchesne, 1996) and memory (Bennetto, Pennington, & Rogers, 1996; Williams, Goldstein, Carpenter, & Minshew, 2005). The control task allowed us to examine the role of these factors in any group differences that emerged.

The pragmatic account and the lexical constraints account predict different patterns of findings in the current study. Critically, the pragmatic account attributes performance on the fact and label conditions to a single, underlying factor: the ability to infer speakers' referential intent. The pragmatic account thus predicts that children in a given diagnostic group should treat words and facts as mutually exclusive to an equivalent degree. With respect to group differences, the pragmatic account predicts that the TD group should perform better than the pragmatically-impaired ASD group on both conditions, since both conditions rely on the ability to infer referential intent. In addition, because exclusivity for facts and exclusivity for words are produced by the same cognitive mechanism, then any individual characteristics that are related to one should be related to the other.

The lexical constraints account, on the other hand, attributes performance on the two conditions to very different factors: the mutual exclusivity constraint in the label condition, and some other process, perhaps social-pragmatic reasoning, in the fact condition. Thus there is no reason to expect the tasks to pattern together in either population. On the lexical constraints hypothesis there is also no reason to expect that participants in the ASD group will be impaired on the label condition, since the lexical constraint that it taps is independent of social-pragmatic skills and the children and adolescents that we are testing do not have intellectual or lexical impairments. While this hypothesis does not make any specific predictions with regard to the fact condition, it leaves open the possibility that performance in this task is driven by social pragmatic skill and will be impaired in ASD. Finally, since performance on the two conditions is thought to be driven by distinct mechanisms, the lexical constraints account leaves open the possibility that individual differences associated with one condition will not be associated with the other.

2. Method

2.1. Participants

Children and adolescents with ASD: Participants were 30 children and 18 adolescents with high-functioning ASD, recruited: from special needs schools in New England, through community groups serving parents of children with special needs, or by word of mouth. Participants were initially selected based on a parent's report that the child both had an ASD (Autistic Disorder, PDD-NOS, or Asperger's Disorder) and had language abilities that were approximately at chronological age level.

Parents of all participants completed the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), a screener for symptoms of ASD. For the younger age group, ASD diagnoses were confirmed through the review of clinical diagnostic reports provided by the parents when these were available. When diagnostic reports were not available children were required to meet criteria for an ASD diagnosis on the SCQ. One participant failed to do so and was excluded. For the older age group, diagnoses were confirmed through the administration of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002), Module 3 or 4, by a trained clinician (AdM). One participant was excluded for failure to meet criteria for an ASD diagnosis on the ADOS.

Receptive vocabulary was assessed with the Peabody Picture Vocabulary Test – Third Edition (PPVT; Dunn & Dunn, 1997). Participants were included who had PPVT scores of 85 or above. Four participants with ASD were excluded for scoring below this cutoff. Thus the final ASD sample consisted of 26 children and 16 adolescents. Participant details are given in Table 1.

Typically developing children andadolescents: The ASD sample was compared to a sample of TD children and adolescents

Table 1
Demographic and symptom severity variables by diagnostic and age group.

	ASD kids M (SD) Range	TD kids M (SD) Range	ASD teens M (SD) Range	TD teens M (SD) Range
N	26	24	16	16
Gender (M:F)	22:4	14:10	14:2	14:2
CA[a] (years)	8.1 (2.3) 4.2–11.8	7.6 (2.2) 4.9–11.9	15.1 (1.2) 13.1–16.9	14.9 (1.3) 12.8–17.6
PPVT (standard score)	112 (19) 87–148	118 (12) 86–139	113 (12) 92–135	119 (8) 105–137
SCQ				
Total	20 (5) 13–31	3 (2) 0–8	21 (7) 10–29	2 (3) 0–9
RSI[b]	6 (3) 1–12	0 (1) 0–2	8 (4) 2–13	0 (1) 0–2
Communication	7 (2) 1–10	2 (1) 0–4	6 (3) 2–9	1 (2) 0–7
RBI[c]	6 (2) 1–8	1 (1) 0–3	6 (2) 1–8	0 (1) 0–2

Note: Fifteen is the threshold on the SCQ for autism spectrum disorders; higher scores indicate greater severity. There were seven children in the ASD group who were below threshold on this parent-report questionnaire. Diagnoses for these participants relied on the existence of pre-existing diagnosis by an experienced professional.

[a] CA = Chronological age.
[b] RSI = Reciprocal social interaction.
[c] RBI = Repetitive behaviors and interests.

who were matched on chronological age and receptive vocabulary. Participants were 52 children and 16 adolescents with a typical developmental history, including no first-degree relatives with an ASD diagnosis, no developmental delays, and no known neurological impairments. Participants were recruited through their schools and via word of mouth. Twenty-eight participants were excluded for the following reasons: failure to match to the ASD group ($n = 20$), high score (above nine) on the SCQ ($n = 4$), experimenter error in task administration ($n = 3$), and for current concerns regarding social impairments ($n = 1$). The final TD group consisted of 24 children and 16 adolescents.

2.2. Standardized measures

The PPVT (Dunn & Dunn, 1997) is a widely used measure of receptive vocabulary from preschool age to adulthood. Participants are presented with four pictures of objects, actions, and events from which they must select the appropriate referent of a word stated by the experimenter. The reliability and validity of this measure are well established.

The SCQ (Rutter et al., 2003) is a 40-item parent questionnaire for the screening of ASD symptoms in children. Items on the questionnaire were derived from the Autism Diagnostic Interview – Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994), which is considered to be a highly valid measure for diagnosing ASD. When used as a screening instrument, a cutoff score of 15 is recommended as an indication of a possible ASD (Rutter et al., 2003).

The ADOS (Lord et al., 2002) is a semi-structured assessment for the diagnosis of ASD, which provides multiple opportunities for social and communicative engagement. The reliability and validity of this measure are well established. Depending on their age and maturity level, participants in this study were administered either Module 3 or Module 4, which are both intended for individuals with fluent speech. The ADOS was administered to adolescent participants only.

2.3. Task design

The experimental task was based on Diesendruck and Markson (2001, Study 1). This task employs a standard exclusivity paradigm for words: participants are shown two novel objects, one of which is given a novel label, then they are asked to choose an object using a second novel label. The same paradigm is also given using facts instead of labels (i.e., rather than labeling and requesting an object with a novel word, an object is described using a novel fact and requested using a second novel fact). These two conditions, hereafter the *label* and *fact* conditions, respectively, were administered within subjects with the order counterbalanced across participants.

A subgroup of participants also received a control task, which was identical to the exclusivity task, except that an object was requested using the same novel label or fact that was given to the first object. This control task was always given after both experimental conditions were completed.

2.4. Stimuli

Twenty-four pairs of novel objects were used in this study. Novel objects consisted of unusual household items (e.g., a tea egg, a yellow plastic drain catcher) or novel artifacts created in the lab (e.g., a plastic lid glued to a wooden craft stick). Each item was distinct in appearance and most participants found them to be both interesting and unfamiliar.

2.5. Novel labels and facts

All novel words were single CVC syllables conforming to the rules of English phonology (e.g., "wug" and "jop"). Novel facts were statements such as "This one is from California" or "This is the one my sister gave me." The twelve novel words and the twelve facts used in the exclusivity task can be found in Diesendruck and Markson (2001; Study 1).

2.6. Procedure: exclusivity task

Label condition: In the training phase of each trial, the experimenter placed a pair of novel objects in front of the participant, one on either side of the table. The experimenter then picked up Object A and engaged the participant in joint attention by alternating her gaze between the child and the object, and looking at the object with fascination. Because attentional impairments in ASD have been noted to interfere with word learning (Baron-Cohen et al., 1997), care was taken to ensure that the child or adolescent's attention was on the object before proceeding. Despite their limitations, children with ASD orient to objects attended to by others when the cues are salient enough (Bayliss & Tipper, 2005). Once the participant was looking at the object, the experimenter looked at it and labeled it three times, saying, "Here's the *jop*. Look this is a *jop*. See the *jop*?" The experimenter then placed Object A back on the table, and picked up Object B. After the participant's attention was on Object B, the experimenter looked at the object and said, "Oh look at this one. Isn't it cool? This is nice." The experimenter then placed Object B back on the table and allowed the participant to explore both objects for approximately 30 s.

After this the experimenter proceeded to the question phase. The experimenter picked up both objects and placed them in their original locations. While looking at the participant (and not at either of the objects) the experimenter asked the participant for the referent of a second novel label, for example, "Can you give me the *wug*?" The experimenter provided no further information, but encouraged the participant to make a selection (e.g., if the participant was reluctant to make a choice, the experimenter stated, "just take your best guess"). After making a choice, the participant was thanked for providing one of the objects, but no explicit feedback was given. This procedure was repeated for six trials. The labeled object (i.e., Object A or Object B) alternated across trials.

Fact condition: The procedure in the fact condition was the same as the label condition, with two exceptions. First, rather than labeling one of the objects with a novel word in the training phase, the experimenter provided a brief factual description, for example, "Look at this one, *my sister gave this to me*. See, *my sister gave this to me*. *My sister gave me this*." Second, during the question phase, the experimenter asked the participant for the referent of a different fact, for example, "Can you give me *the one my dog likes to play with*?"

The specific stimuli used for each condition, the side of presentation of these stimuli, and the order in which the label and fact conditions were presented were fully counterbalanced across participants. To minimize the chance that participants would directly apply strategies that they had formed in the first condition to the second condition, the second condition was administered no sooner than 2 weeks after the first, with the exception of two adolescents with ASD who were given the second session after a delay of several hours.

2.7. Procedure: memory control task

Twenty-seven participants with ASD (20 children, 7 adolescents) and 24 participants with TD (10 children, 14 adolescents) also completed a memory control task to test for differences in attention and memory that could affect performance on the experimental task. The procedure for the control task consisted of the same training phase as the mutual exclusivity task. In the question phase, however, the participant was queried using the *same* label or fact that was used in the training phase. For example, during for the label condition, the experimenter would describe Object A as follows: "Look at this one, it's a tog. See, it's a tog. This is a tog," and in the question phase, would ask, "Can you give me the tog?" For the fact condition, the experimenter would describe Object A as follows: "Look at this one, I keep this in my closet. See, I keep this in my closet. I keep this in my closet," and in the question phase, would ask, "can you give me the one I keep in my closet?" This task was always administered subsequent to both the experimental label and fact conditions.

All children were tested in a quiet room that was free from distractions. Testing took place in the participant's home or school or in our laboratories at Harvard University or the University of Connecticut. On the first day of testing, participants completed the PPVT, ADOS (adolescent participants only), and the first condition (either label or fact) of the exclusivity task. Parents were also given the SCQ to complete. ASD participants who met inclusion criteria and TD participants who met inclusion criteria and were appropriately matched to the ASD group were invited back for a second day of testing, during which they completed the second condition of the mutual exclusivity task, and (for 51 participants) both conditions of the memory control task. In all cases, the experimenter was the same for both days of testing. Participants were always seated across a table from the experimenter. A digital camera was positioned behind the experimenter to videotape participant responses.

3. Results

We found no significant differences between our two age groups, therefore all data is presented collapsed across age groups.

3.1. Task performance: exclusivity task

A two-way repeated measures ANOVA with diagnostic group and condition as independent variables and task success (i.e., the proportion of unlabeled object choices) as the dependent variable revealed a significant main

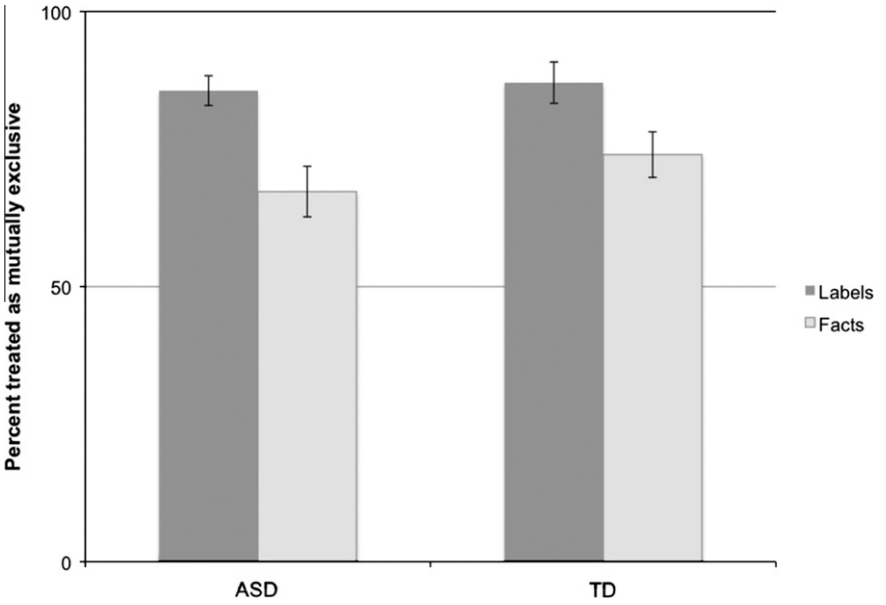

Fig. 1. Percentage of trials on which participants treated labels and facts as mutually exclusive, by diagnostic group. Chance performance for both conditions is 50%; *t*-tests against chance performance for all four cells were reliable ($p < .001$).

effect of condition, $F(1, 80) = 15.30$, $p < .001$, partial $\eta^2 = 0.16$. The main effect of diagnostic group was nonsignificant, $F(1, 80) = 1.20$, $p = .28$, partial $\eta^2 = 0.02$, as was the group by condition interaction, $F(1, 80) = 0.43$, $p = .51$, partial $\eta^2 = 0.01$. These findings suggest that participants with ASD and participants with TD performed similarly on both conditions. Post hoc *t*-tests revealed that labels were treated as mutually exclusive more reliably than facts by both the ASD group $t(41) = 3.40$, $p = .002$, Cohen's $d = 0.77$, and the TD group, $t(39) = 2.22$, $p = .03$, Cohen's $d = 0.53$ (Fig. 1).[3] This discrepancy suggests that different mechanisms underlie performance on the fact and label conditions. Although participants were more likely to choose the unlabeled object in the label condition than in the fact condition, performance for both groups was above chance on both conditions (ASD label, $t(41) = 31.70$, $p < .001$, Cohen's $d = 2.03$; ASD fact, $t(41) = 14.62$, $p < .001$, Cohen's $d = 0.58$; TD label, $t(39) = 23.22$, $p < .001$, Cohen's $d = 1.57$; TD fact, $t(39) = 17.86$, $p < .001$, Cohen's $d = 0.92$).

To investigate effects of order, separate two-way ANOVAs were performed on the label and fact conditions, with diagnostic group and condition order as independent variables, and task success as the dependent variable. For the label condition, there was no significant main effect of group, $F(1, 78) = 0.09$, $p = .77$, partial $\eta^2 = 0.001$, or order, $F(1, 78) = 0.42$, $p = .52$, partial $\eta^2 = 0.01$, and no group by order interaction, $F(1, 78) = 2.18$, $p = .14$, partial $\eta^2 = 0.03$. For the fact condition, there was no main effect of group, $F(1, 78) = 1.65$, $p = .20$, partial $\eta^2 = 0.02$, and no group by order interaction, $F(1, 78) = 1.93$, $p = .17$, partial $\eta^2 = 0.02$. However, for the fact condition only, the main effect of order was significant, $F(1, 78) = 12.91$, $p = .001$, partial $\eta^2 = 0.14$ (order effect presented in Table 2). Children and adolescents who received the fact condition in the second session (and, therefore, had experienced one version of the task) performed significantly better on the fact condition than children and adolescents who received the fact condition first and had no task experience. In other words, participants were more likely to treat facts as mutually exclusive once they had already done so with labels. In contrast, condition order had no effect on label performance; that is, prior experience with the fact task did not increase participants' tendency to treat labels as mutually exclusive. This order effect suggests that participants generalized from the label condition to the fact condition, but not from the fact condition to the label condition.

A fundamental question of the current study is whether performance on the label and fact condition is driven by the same or different underlying mechanisms. If the same form of reasoning underlies performance on both conditions, then successful performance on these two tasks should be correlated. In fact, label performance was uncorrelated with fact performance for the sample as a whole, Spearman's rho $(82) = .04$, $p = .76$, and within each diagnostic group (ASD: Spearman's rho $(42) = .09$, $p = .59$; TD: Spearman's rho $(40) = -.07$, $p = .66$). This finding suggests that performance on the two conditions is supported by distinct mechanisms.

3.2. Individual difference analyses

At the group level, participants with ASD and participants with TD performed equally well on both the label and fact conditions. We were further interested in how individual differences in social pragmatic skill might relate to task performance. To explore these possible effects, we

[3] Because of the non-parametric nature of the task performance data, all critical results were checked with non-parametric analyses. These analyses produced the same pattern of findings as that reported above.

Table 2
Proportion of responses treated as mutually exclusive, by order, group, and condition.

	Tested first	Tested second	Improvement[a] (%)	*t*(*df*)	*p*
ASD					
Label *M* (*SD*)	90% (15)	81% (19)	−9	1.85 (40)	.07
Fact *M* (*SD*)	61% (32)	74% (27)	+13	1.40 (40)	.17
TD					
Label *M* (*SD*)	85% (24)	89% (24)	+4	−0.50 (38)	.62
Fact *M* (*SD*)	60% (22)	89% (22)	+29	4.12 (38)	<.001

Note: Values in the *Tested first* column represent the percent of unlabeled object choices for the first condition administered. Values in the *Tested second* column represent performance on the second condition administered. *Improvement* values reflect the mean difference between participants who received the given condition first and those who received the condition second. *T*-tests were performed to test this mean difference.

compared individual performance on the label and fact conditions to scores on a measure of socio-communicative impairment, the SCQ. Due to the non-parametric nature of the task performance data, Spearman's rho was used for correlation analyses. Children and adolescents who treated facts as mutually exclusive more reliably were found to have lower SCQ communication scores (i.e., fewer behaviors associated with ASD communication symptoms); Spearman's rho (75) = −.29, $p = .01$. This finding suggests that the fact condition taps social-pragmatic skills. In contrast, participants' SCQ communication scores were not correlated with performance on the label condition, Spearman's rho (75) = −.10, $p = .41$, suggesting that social-pragmatic skills are unrelated to performance on the label condition.

If exclusivity inferences support vocabulary development, then we should expect that children and adolescents who are more successful on an exclusivity task will have larger vocabularies. To test this hypothesis, we compared our participants' performance on the label condition with their receptive vocabulary size, as assessed by the PPVT. PPVT standard scores were significantly positively correlated with performance on the label condition, Spearman's rho (82) = .40, $p < .001$, but not with performance on the fact condition, Spearman's rho (82) = .17, $p = .13$. Children and adolescents who consistently treat words as mutually exclusive have larger receptive vocabularies, whereas children who treat facts as mutually exclusive do not.[4]

Because both diagnostic groups had similar success rates on the label and fact conditions, one might assume that participants from both groups succeeded on the task via the same inferential processes. An alternate possibility, however, is that participants with ASD approached the task differently than participants with TD, and thus that different mechanisms underlie performance in the two groups. To test this possibility, we performed the same individual difference measures, reported above, separately for each diagnostic group. After splitting the sample by diagnosis, label condition performance remained strongly correlated with receptive vocabulary scores in both the ASD, Spearman's rho (42) = .36, $p = .02$, and TD, Spearman's rho (40) = .36, $p = .02$, groups. For the fact condition, the relationship between SCQ communication scores and performance did not reach significance in either group (ASD: Spearman's rho (40) = −.27, $p = .10$; TD: Spearman's rho (35) = −.15, $p = .39$), although the direction of the effect was in the predicted direction. This is not surprising, our inclusion criteria ensured that the ASD group would have high SCQ scores and the TD group would have low SCQ scores, consequently the range of scores in the subgroup analyses was restricted, reducing the sensitivity of this analysis. Thus, while these results are not definitive, the overall pattern of findings is parallel for the ASD and TD groups, and does not suggest that the two samples approached the task differently.

3.3. Task performance: memory control task

Twenty-seven participants with ASD and 24 participants with TD also completed a memory control task to test for the possibility of differences in attention and memory for the two conditions that may have affected performance. We found that memory for facts was significantly better than memory for labels, $t(50) = 2.634$, $p = .01$, Cohen's $d = 0.47$, removing any concern that the facts were simply harder to process or retain. After comparing performance on the experimental task to performance on the control task, we found that participants were as successful on the experimental label condition as they were on the control label condition, $t(50) = .242$, $p = .81$, Cohen's $d = 0.06$. In contrast, participants performed significantly worse on the experimental fact condition than the control fact condition, $t(50) = 5.25$, $p < .001$, Cohen's $d = 1.04$, with a large effect size (Fig. 2). The use of a mutual exclusivity strategy for labels was as efficient as explicitly being taught an object label. In contrast, using mutual exclusivity to identify the referent of a fact was significantly less reliable than simply being taught a fact about an object.

[4] The same pattern of results was found in a regression analysis in which SCQ communication scores and PPVT standard scores were tested as predictors of performance on the fact and label conditions. SCQ communication scores and PPVT standard scores were entered simultaneously into the regression. For the label condition, the overall regression was significant, $R^2 = .16$, $F(2, 72) = 6.89$, $p = .002$. This effect was driven entirely by the contribution of receptive vocabulary; PPVT scores were a significant predictor of label performance, $t(72) = 3.707$, $p < .001$, $\beta = .407$, while SCQ communication scores were not, $t(72) = 0.492$, $p = .624$, $\beta = .054$. For the fact condition, the overall regression was also significant, $R^2 = .08$, $F(2, 72) = 3.18$, $p = .047$. In contrast to the label condition, the regression for the fact condition was driven entirely by the contribution of social-communicative skills; SCQ communication scores significantly predicted fact performance, $t(72) = -2.074$, $p = .042$, $\beta = -.238$, while PPVT scores did not, $t(72) = 1.038$, $p = .303$, $\beta = .119$. These findings are consistent with the correlations reported above and further suggest that label performance is associated with vocabulary skill, while fact performance is associated with social communicative skill.

When we include only participants who achieved perfect performance on both the label and the fact control conditions ($N = 31$), we continue to find that labels are treated as mutually exclusive more reliably than facts (label mean: 94% correct, fact mean: 75% correct; $t(30) = 3.04$, $p = .005$, Cohen's $d = 0.77$). After splitting perfect performers by diagnostic group, we found that, although both groups performed better on the label condition (ASD mean: 94% correct, TD mean: 94% correct) than on the fact condition (ASD mean: 61% correct, TD mean: 85% correct), this difference only reached significance in the ASD group, $t(12) = 3.22$, $p = .007$, Cohen's $d = 1.14$, and not in the TD group, $t(17) = 1.27$, $p = .22$, Cohen's $d = 0.46$.

4. Discussion

The current study was designed to contrast two competing hypotheses about the nature of the mutual exclusivity constraint in word learning. According to one account, the pragmatic account, mutual exclusivity is one manifestation of a broader tendency to assume that speakers will use the same form for a given referent within a single discourse – that there is a one-to-one correspondence between referents and forms. This pragmatic account is consistent with Hypothesis A (see Section 1), that a single factor underlies performance on both label and fact conditions. In contrast, according to the lexical constraints account (consistent with Hypothesis B), mutual exclusivity is specific to word learning, and does not apply to other speech acts. On this account, distinct factors are proposed to underlie children's tendency to treat words and facts as mutually exclusive. In the present study, we found that children and adolescents with ASD and children and adolescents with TD showed mutual exclusivity for both words and facts; however, this tendency was much stronger for words than for facts. The control task demonstrated that this relationship was not due simply to facts being harder to process or remember. Because our sample included children with variable pragmatic and linguistic skills, we were able to examine individual differences in performance. We found that performance on the label and fact conditions was uncorrelated and that the label and fact conditions were associated with different variables. Specifically, children with better social-communication skills were more likely to treat facts as exclusive, suggesting that pragmatic skills underlie this ability. In contrast, children with larger vocabularies were more likely to treat words as exclusive, suggesting a connection to lexical skills. These findings strongly suggest that distinct mechanisms underlie performance on the label and fact conditions. Here we will review the implications of these findings for mutual exclusivity in ASD and the feasibility of the pragmatic hypothesis of mutual exclusivity, and then revisit the domain-specific lexical hypothesis and the domain-general hypothesis in light of these results.

4.1. Mutual exclusivity in ASD

Children and adolescents with ASD offer a unique window into typical language acquisition processes. By studying the ways in which these remarkable individuals learn language despite their significant impairments in social interaction and nonverbal communication skills, we may gain additional leverage on the contribution of the different skills that children bring to the task of language acquisition. In addition to contributing to our understanding of typical language development, this paper offers insight into word learning processes for children with ASD. Specifically, we extend Preissler and Carey (2005) by

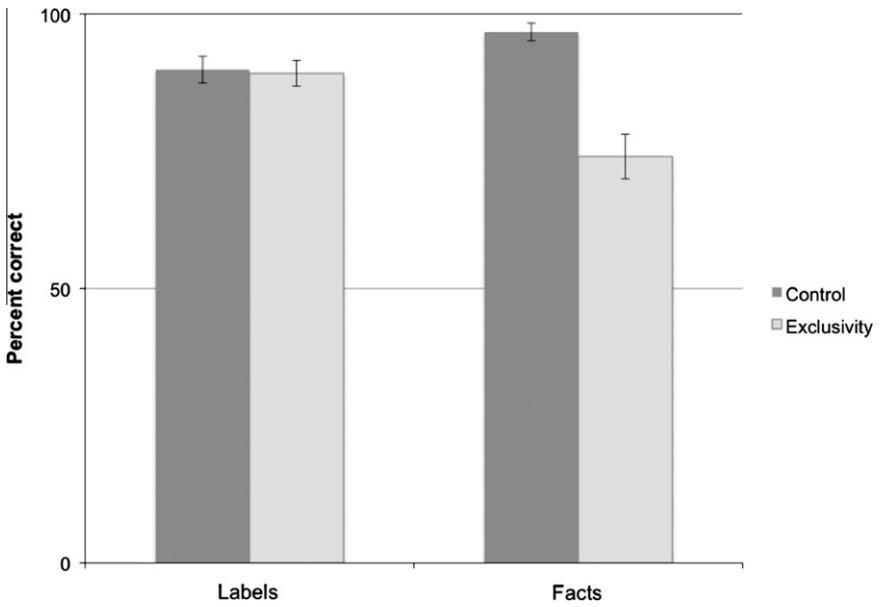

Fig. 2. Comparison of control task and exclusivity task for participants who received both. For the control task the correct referent is the labeled object, for the exclusivity task the correct referent is the unlabeled object.

demonstrating that individuals with ASD use mutual exclusivity to successfully determine the referents of novel words, in the absence of any confound between novelty and exclusivity.

One limitation of our study is that we included only children and adolescents with high-functioning ASD; the present findings may not generalize to low-functioning children. Preissler and Carey's (2005) study demonstrates that even nonverbal children succeed in a novelty task, suggesting that, at the very least, a novelty preference for words is present in children at all points along the autism spectrum. This conclusion is supported by a recent study of word learning in children with ASD with substantial language impairments (Parish-Morris et al., 2007). In an experiment exploring the role of perceptual salience in word learning (Experiment 2), the authors included a probe with the essential features of an exclusivity task (two objects, one labeled directly, the other requested with a second label). The results suggested that these 3- to 7-year-olds with ASD treated the second label as mutually exclusive.[5] In sum, the current evidence suggests that, despite impairments in social pragmatics, individuals with ASD, across age and ability levels, use mutual exclusivity to learn words.

Nevertheless, there appear to be individual differences in the effectiveness with which children with ASD employ this strategy or the degree to which they adhere to it. Our finding that strong use of mutual exclusivity was related to vocabulary knowledge might predict a lower degree of adherence to mutual exclusivity in lower functioning children (with lower vocabulary levels). Consistent with this conjecture, adherence to exclusivity in the Parish-Morris et al. (2007) study is substantially lower than in the present experiment (70% vs. 86%), though the methodological differences between the two experiments make this difference difficult to interpret. Additional research will be required to determine whether adherence to mutual exclusivity is a cause of greater vocabulary knowledge. The correlation could potentially reflect effects of variation in phonological processing and verbal working memory on both vocabulary acquisition and memory for the first novel word in this exclusivity task.

4.2. Testing the pragmatic hypothesis

The pragmatic account proposes that a single mechanism (e.g., the principle of contrast) underlies both the tendency to treat words contrastively and the tendency to treat facts contrastively. Thus it follows that performance on the label and fact conditions should be correlated, and that any individual differences that are associated with mutual exclusivity for words should also be associated with mutual exclusivity for facts. We found that the predictors of performance for the two conditions were different and that performance across the two conditions was uncorrelated, suggesting that distinct mechanisms drive mutual exclusivity for words and mutual exclusivity for facts.

Individual performance on the label condition was positively correlated with receptive vocabulary ability. This finding is consistent with previous work with infants that found a positive association between expressive vocabulary size and performance on a novelty task (Graham et al., 1998). These are important findings, because they confirm that the tendency to avoid lexical overlap may be critical to vocabulary development. In the present study, performance on the fact condition was not correlated with performance on the receptive vocabulary test. This finding is difficult to interpret within a pragmatic account of word learning, which proposes that vocabulary development is grounded in the same referential inference process that allows children to interpret facts as mutually exclusive in this task.

Although unrelated to vocabulary size, the fact condition was associated with ASD communication symptoms, such that children with better communication skills were more likely to treat facts as mutually exclusive. This finding supports the premise that the fact condition depends on children's pragmatic abilities, as Diesendruck and Markson (2001) suggest. In contrast, performance in the label condition was not associated with communication symptoms. Again, this is problematic for the pragmatic hypothesis, which proposes that the same pragmatic skills should underlie the contrastive interpretation of words. Taken together, individual difference measures suggest that the two conditions are associated with different factors: the label condition with vocabulary, and the fact condition with communication and social-pragmatic skills. This pattern of differential correlation also suggests that the critical associations are not solely attributable to a common association with some domain-general factor (such as IQ), which would presumably influence performance in both conditions equally.

Our findings suggest that mutual exclusivity for words is more robust than mutual exclusivity for facts. Although both groups performed above chance in the fact condition, performance was considerably lower than it was in the label condition. In fact, our data suggests that older children and adolescents are actually less likely to treat facts as contrastive than 3-year-olds are. The first block of trials in our within subjects design is comparable to the between subjects design used in Diesendruck and Markson (2001); the tasks used similar stimuli and procedures, and the same labels and facts. The 3-year-olds in that experiment succeeded on 82% of the label trials and 73% of the fact trials. Our TD sample of older children and teens showed similar performance for words (85%) but lower performance for facts (60%). Critically, the mean for facts performance in the Diesendruck and Markson study is not within the 95% confidence interval for our data, suggesting that 3-year-olds are *more* likely to treat facts as mutually exclusive than older children and adolescents. This could reflect deeper processing of the facts by the older children. In both studies, the facts were paired so that they would not logically exclude one another (my sister gave it to me vs. I keep it under my bed). The older children in this study may have been more adept at determining

[5] Because these authors were not specifically interested in mutual exclusivity, they did not present any statistical analyses to support the presence of this bias. However, the data that is reported suggests that mutual exclusivity is present in this population (Table 3, Parish-Morris et al., 2007).

when facts are incompatible, and thus may have realized that both facts could be used to refer to the same object. They may also be more accustomed to hearing a single object described in multiple ways, or be more able to think about an object in multiple ways (see e.g., Flavell, Flavell, & Green, 1983).

The order effect observed in this study provides further support for the robustness of mutual exclusivity for words. Participants in our study showed an asymmetric pattern of generalization (Table 2). Those who received the label condition before the fact condition were far more likely to make the contrastive inference for facts, suggesting that they generalized a robust exclusivity strategy from words to facts. In contrast, participants who received the fact condition before the label condition performed no better on the label condition, suggesting that they were not able to generalize from the fact to the label condition. This asymmetry suggests that participants initially bring very different strategies to the label vs. the fact tasks. In the label task, participants have an available strategy that supports a robust contrastive inference (e.g., a lexical constraint) which is not, initially, available in the facts task. However, they seem to generalize from this lexical strategy when confronted with a parallel task involving novel facts (perhaps by thinking of the facts as names or labels). In contrast, participants who received the facts task first did not initially appear to have access to a stable, consistent strategy. This was apparent in some of the older participants' reactions to the fact task – despite above chance performance, many stated that they were "just guessing."

The control task allowed us to look only at participants who were reliably able to remember novel labels and facts (i.e., those who were at ceiling on both control conditions). We found that the TD group was equally likely to treat labels and facts as mutually exclusive; the ASD group, however, treated labels as mutually exclusive more reliably than facts. Thus, when we remove some of the variability associated with faltering attention and memory, we find that the fact condition is sensitive to diagnostic status, unlike the label condition, further suggesting that performance on the label condition does *not* depend on social pragmatics.[6]

4.3. Alternate construals of the pragmatic hypothesis

It is worth considering whether the systematic differences that we observed between the label task and fact task could be accounted for by some version of the pragmatic account. Below we consider three ways in which this might be done.

Possibility 1: Exclusivity inferences reflect a common set of pragmatic processes which apply differently to words and facts. Diesendruck and Markson note that *two* of Clark's pragmatic principles (1990) are relevant for understanding exclusivity. The first is the principle of contrast—different linguistic forms express different communicative intentions—which applies to all speech acts and thus contributes equally to the interpretation of facts and labels. The second is the principle of conventionality which posits that certain linguistic forms are conventionally used to express particular meanings by all members of a linguistic community. Words are generally conventional forms, facts typically are not (Diesendruck & Markson, 2001). This offers a potential explanation for our data pattern. Exclusivity for words is supported by conventionality as well as contrast and thus is more robust than exclusivity for facts, accounting for the children's higher performance in the label condition. If the two pragmatic principles are tied to different cognitive skills, this might explain the different patterns of correlations observed across the two tasks. We see two challenges for such an account of our findings.

First, invoking the principle of conventionality for discourse contexts like ours would require a departure from the previous literature – one which would make it difficult for the pragmatic theory to account for earlier findings. Previous studies of *conventionality* require children to make inferences from one speaker to another or from their prior knowledge of the language to a new speaker (see e.g., Diesendruck, 2005; Diesendruck, Carmel, & Markson, 2010). For example, Diesendruck and Markson (2001, Study 2) examined whether children would treat facts (or words) as exclusive across speakers. The two speakers in the study were the experimenter and a puppet. At the beginning of each trial, the puppet would disappear to a location where it could not hear the interaction. Then the experimenter would produce the first novel fact, after which the puppet would return and request an object using the second novel fact. Under these circumstances children did not treat facts as mutually exclusive, but did treat words as exclusive. The authors argue that this is because words, but not facts, are conventional.

Thus, on the pragmatic theory, conventionality is necessary to infer that a particular speaker knows or could use a given label. This inference of knowledge is not relevant in contexts, like the present experiment, in which the speaker has just produced the contrasting label three times and thus clearly knows it. Of course, a pragmatic theory could be constructed which specifies that conventionality is relevant to exclusivity inferences, even when the contrasting form has been used by the same speaker in the same discourse. But such a theory would fail to explain the results of Diesendruck and Markson's first experiment, in which 3-year-olds treated two facts produced by the same speaker as mutually exclusive. If conventionality is relevant for contrast, even within a single conversation, then this data pattern is unexpected (since facts are not conventional, see above). If conventionality is not involved in exclusivity

[6] We do not wish to suggest that social pragmatics play no role in word learning. In fact, there is clear evidence that social *attentional* cues such as gaze direction (Baldwin et al., 1996) and joint attention (Woodward, Markman, & Fitzsimmons, 1994), and social *intentional* cues, such as discourse novelty (Tomasello & Akhtar, 1995) and the purposefulness of labeling acts (Diesendruck, Markson, Akhtar, & Reudor, 2004), contribute to word learning. Further, children's interpretations of speakers' communicative intentions may override their default assumptions (e.g., constraints) about word-object mappings, for example, in the presence of explicit instruction (Diesendruck, Markson, & Bloom, 2003) or unreliable speakers (Scofield & Behrend, 2008). What we wish to emphasize is that the ability to understand communicative intent does not appear to play a major role in the mutual exclusivity bias, which is intact in children and adolescents with ASD despite their significant impairments in pragmatics and social communication.

inferences under these conditions, then it cannot be invoked to explain the difference between the words and facts in the present study.

Second, a theory invoking these two pragmatic constraints does not readily account for the patterns of correlation that we observed. Contrast and conventionality are conceived of as two pragmatic principles that work in concert. Contrast is always required for the exclusivity inference but the range of contexts in which a form is considered contrastive depends upon conventionality. If children with autism were poor at using contrast, then this should have impacted their performance on words as well as facts.[7] Similarly, on this hypothesis we would expect that the correlation with social symptoms would persist in the words task and that performance in the words task would correlate with performance in the facts task (since both draw on the principle of contrast).

Possibility 2: Typically developing children use a pragmatic mechanism for exclusivity inferences for words (mechanism A), while children with ASD use a non-pragmatic mechanism (mechanism B). Thus the pragmatic theory is correct for the population that it seeks to characterize. Three considerations lead us to reject this hypothesis.

First, nothing in our data suggests that the TD and ASD groups used different mechanisms in the label conditions. In both groups, performance correlated with vocabulary scores but not social communicative symptoms. In both groups, performance on the label condition was high regardless of whether it came before or after the fact condition. Second, this hypothesis would predict that performance in the label and fact conditions would be correlated in the TD group but not in the ASD group, but this correlation was absent in both populations.

Finally, it is unclear how (or why) two mechanisms for mutual exclusivity would arise over development or evolution. It is unlikely that evolution has provided children on the spectrum with linguistic resources above and beyond those available to typical children. Thus, TD children presumably have mechanism B as well, or at least the capacity to develop it. If mechanism B was less effective than A then this would be unproblematic: ASD children, lacking the right tools for the job, may have cobbled together a strategy for solving the task, while TD children have the right tools and thus do not need to fall back on this less effective approach. But in the present case, children with ASD perform as well as age-matched TD peers. This cannot be attributed to ceiling effects: in both groups there is considerable variation across individuals, which is correlated with vocabulary size. Thus, if there are two mechanisms, they appear to be equally well-suited to the task, and we must explain why both exist when either one alone could do the job.

This is problematic for any theory in which the development of these mechanisms, in phylogenetic or ontogenetic time, is assumed to be motivated rather than accidental. Solving a problem once removes the need to solve it again. For example, we could suppose that mechanism B is an evolutionarily old, domain-general preference for one-to-one mappings which would explain the apparent use of mutual exclusivity in parrots, dogs and chimps (Kaminski, Call, & Fischer, 2004; Pepperberg & Wilcox, 2000; Savage-Rumbaugh et al., 1993). In contrast, we might imagine that mechanism A is a rich pragmatic inference that develops over the first 3 years of life as children integrate the principle of contrast, the principle of conventionality, and their changing knowledge of what constitutes a conventional form. But note that TD children, by hypothesis, have mechanism B and that this mechanism is as effective at solving the problem since, by hypothesis, it accounts for the performance of the children with ASD. What would motivate TD children to jettison this simple cognitive bias and replace it with the more complicated inference? Alternatively, one could argue that mechanism A is a pragmatic inference that was in place prior to the evolution of mechanism B (which might be a domain-specific lexical constraint). But note that mechanism B is only of value to children who have ASD (since mechanism A can fully support exclusivity inferences in TD kids). Thus it is unlikely that there would be sufficient selection pressure to account for the evolution of this trait.

Possibility 3: Exclusivity for words and exclusivity for facts are subserved by two distinct processes, both of which are pragmatic.

As a theoretical construct, pragmatics is loose at best. Within linguistics and psycholinguistics, pragmatics encompasses all aspects of meaning conveyed by an utterance beyond what is semantically encoded and so it defines a complement set (like *not frogs*, or *context*). We know of no reason to believe that this complement set corresponds to a natural cognitive kind. In fact, recent research on language comprehension in ASD suggests that pragmatic processes are of (at least) two kinds. Some pragmatic processes, such as scalar implicature, appear to depend entirely on grammatical skills and thus are impaired in children with nonsocial language deficits and unimpaired in highly verbal people with ASD (Chevallier, Wilson, Happé, & Noveck, 2010; Katsos, Roqueta, & Estevan, in preparation; Pijnacker, Hagoort, Buitelaar, Teunisse, & Geurts, 2009. Other pragmatic processes (such as the interpretation of irony or relevance implicatures) are impaired in ASD even when verbal abilities are factored out and correlate with measures of social cognition (see e.g., Happe, 1993; deVilliers, deVilliers, Coles-White, & Carpenter, 2009).

These findings suggest an alternate pragmatic hypothesis for exclusivity inferences. Exclusivity for words is subserved by an algorithmic pragmatic process, similar to the one that supports scalar implicature. Individual differences in this ability are primarily linked to linguistic ability and it is unimpaired in highly verbal children with autism (like those in the present study). Exclusivity for facts is

[7] The control task demonstrated that facts were processed as well as words following an ostensive labeling act; however, one possibility that we did not directly address is that facts may be harder to process in a disjunctive context than words. If this were the case, however, we would anticipate that our typically developing participants would have performed better on the fact condition than Diesendruck and Markson's (2001) participants, who were significantly younger, and had fewer cognitive resources available to them. This was not the case, suggesting that something other than disjunctive skill is driving the difference between the word and fact conditions.

subserved by a richer pragmatic process that draws on our knowledge of social communication interactions. Individual differences in this process are thus correlated with social and communicative symptoms and the process is often impaired in children with ASD. Clearly, this revised pragmatic hypothesis can account for the present data. But it does so by accepting many of the premises of the lexical account. It simply nudges the location of the word learning constraint over the border from core language and into less charted territory of pragmatic inference.

4.4. The lexical constraints hypothesis for mutual exclusivity

Our finding that exclusivity is stronger for words than it is for facts is fully predicted by the hypothesis that mutual exclusivity is a domain-specific constraint that is limited to word learning. Specifically, the lexical constraints account predicts that in situations of referential ambiguity, lexical constraints will provide a strategy for disambiguation that is available only to words, and not to other speech acts. It follows that words should be treated as mutually exclusive more consistently than facts, which is precisely what the present data suggests. In fact, our control experiment demonstrated that, in the case of words, referential disambiguation via mutual exclusivity was as robust as referential disambiguation via ostensive naming; not so for facts.

From a functional perspective one might wonder why a lexical constraint would exist when a general pragmatic bias is available as well. We see three possible advantages to having this domain-specific mechanism. First, all data to date suggests that exclusivity for facts emerges during the preschool years, long after exclusivity for words (Markman et al., 2003; Scofield & Behrend, 2007). This suggests that the pragmatic abilities that underlie contrastive inferences for referential acts in general may develop too late to help word learning get off the ground. For developmental psychologists this may seem counter-intuitive: given the mounting evidence for sophisticated social reasoning in infants, it may seem surprising that toddlers would struggle with what seems like a simple social inference. But this failure is fully consistent with work on children's ability to calculate pragmatic inferences about the interpretation of linguistic forms. On the pragmatic hypothesis, mutual exclusivity involves the recognition that using the novel form to refer to a previously labeled object would constitute a violation of a pragmatic principle (Clark's principle of contrast or Grice's maxim of manner). There is an extensive body of evidence demonstrating that the ability to make inferences on the basis of violations of Gricean maxims develops gradually over early and middle childhood (see e.g., Noveck, 2001; Papafragou & Musolino, 2003; Huang & Snedeker, 2009).

Second, having a lexical constraint as well as a general pragmatic bias would allow exclusivity inferences for words to be sensitive to different factors than exclusivity inferences for other forms. Descriptively, and perhaps normatively, exclusivity inferences for count nouns pattern differently than those for facts or other forms. Specifically, the inference that count nouns within a language are exclusive is applied robustly across speakers and conversations, while exclusivity inferences for proper nouns, facts or count nouns across languages are generated only within the context of a single conversation (see e.g., Diesendruck, 2005; Diesendruck & Markson, 2001). This distinction is readily captured by a theory which posits a lexical constraint for count nouns (which makes no reference to the speaker or her knowledge state) and a general pragmatic bias which affects our interpretation of shifts in referential form across a given discourse.

Finally, having a separate constraint to treat words as mutually exclusive could allow children to adjust the strength of this lexical bias without altering the strength of any commitment they might have about the contrastiveness of other referential acts. The existing evidence suggests that exclusivity for words and facts have very different developmental trajectories. Exclusivity for words is strong from infancy on but becomes more robust with time; exclusivity for facts appears to peak at around 4 years of age. This could reflect differences in the normative value of each bias at different ages. The factors which influence the contrastiveness of referential acts are potentially different than the factors which influence the degree to which objects labels are mutually exclusive. If the biases arise via separate mechanisms, then, in an adaptive learning system, they could potentially be adjusted independently or conditioned on different information.

In sum, our results are fully consistent with the lexical constraints hypothesis. Both children and adolescents appear to have a domain-specific bias to assume that words refer to mutually exclusive categories of objects. But demonstrating that a cognitive mechanism is domain specific at given point in development does not tell us about its developmental history. Domain-specific biases might arise from domain-general learning mechanisms (Karmiloff-Smith, 1998; Smith, 1999; Smith et al., 2002). In the next section, we examine the constraints that our data place on domain-general theories of mutual exclusivity.

4.5. Domain-general hypotheses for mutual exclusivity

On the face of it, our findings seem problematic for domain-general accounts of mutual exclusivity. Accounts of this kind attribute mutual exclusivity to general properties of learning systems such as competition between representations during processing and acquisition or a general tendency to prefer simpler hypotheses or one-to-one mappings (Frank et al., 2009; Regier, 2003). The resilience of mutual exclusivity in children with pragmatic deficits is expected on these theories. However, the discrepancy between exclusivity for facts and words is not. If a bias for one-to-one mappings is simply attributable to a general property of all learning devices, then we should expect this bias to emerge equally in both conditions.

Thus there is clearly one sense in which mutual exclusivity is domain-specific: by middle childhood it applies robustly to words but only weakly (if at all) to facts. But this domain-specific behavior could arise from learning processes that are largely domain-general. There are several ways in which this might transpire.

First, one could envision two parallel systems of mappings, built out the same domain-general pieces, which

gradually diverge over development. Perhaps both the mappings from words to their referents and the mappings from facts to objects are achieved by associative networks with an initial bias for one-to-one mappings. If this bias were adaptive, so that it could be strengthened when the data supported it or weakened when it was counterproductive, then the two systems might diverge over time (see Smith et al., 2002 for a similar account of the shape bias). Such an account would be consistent with the developmental trajectory that emerges when we compare the present study with Diesendruck and Markson (2001). Three-year-olds may initially treat facts and words as exclusive, based on a domain-general bias for simple mappings. As children gain more experience with facts, they may learn that most objects are associated with a range of facts both within and across speakers, which could lead them to adjust their bias accordingly. In contrast, while a given object *can* be described by more than one count noun, our strong tendency to repeatedly use the same high frequency basic level terms may ensure that mutual exclusivity remains an adaptive bias for word learning. Developmental change of this kind would be consistent with the domain-general, adaptive accounts offered by Smith (1999); Smith et al., 2002) and Regier (2005).

Second, in domain-general models of mutual exclusivity, the bias arises because word learning is viewed as a mapping process between stable forms at two (or more) levels of representation. If a problem is not represented in this way, it is not clear that an exclusivity bias would be expected. Facts, unlike simple words, have internal structure. When we interpret a fact we do not simply map the form to a referent or concept, we construct a representation of its meaning though a process of semantic composition. Thus if exclusivity only emerges in systems that learn simple, stable mappings, facts might not be affected.[8]

A closer look at Frank et al.'s (2009) model hints at some of the ways in which domain-specific data patterns like ours could arise from a combination of domain-specific levels of representation and a domain-general learning algorithm. Frank models word learning as involving two mappings. First, there is a mapping that is made between objects in a given context and the word tokens that are uttered, mediated by a representation of the speaker's intentions. Second, there is a mapping between word types and object categories which forms the lexicon and is assumed to be stable across situations. In its current instantiation the model is not equipped to handle facts and their meanings (it lacks compositional semantics, treats a word as the unit of reference, and represents the world as consisting solely of objects). However, any version of this model that did represent the referential use of facts would presumably have to do so by mapping tokens of factual descriptions to their referents via the model of the speaker's referential intentions. A pragmatic bias might be captured at that level. It is not clear that these mappings would or should result in lexical entries since the words that compose the facts all have other uses and thus appear when the reference object is absent. In the case of two novel objects, it appears that exclusivity effects in the model would arise solely from a bias for one-to-one *lexical* mappings (see discussion of Xu, 2002 in Frank et al., 2009). If facts do not have lexical entries then no such bias is expected.

In sum, the current study was not designed to compare domain-specific lexical accounts with domain-general emergentist accounts, and our findings are consistent with both the possibility of a domain-specific lexical constraint, and with the possibility of a domain-general mechanism that gives rise to a strong bias for mutual exclusivity in words but not in facts.

4.6. Final words

Our results demonstrate that high-functioning children with ASD can use mutual exclusivity to infer that a novel word refers to an object that has not been named. This extends the findings of Preissler and Carey (2005) by showing that children with ASD are not merely matching novelty-to-novelty but actually interpreting words as referring to mutually exclusive categories of objects. Furthermore, we found that exclusivity for words was more robust in several respects than exclusivity for facts, both in typically developing children and in children with ASD. Mutual exclusivity for words was associated with vocabulary size while mutual exclusivity for facts was associated with social-pragmatic skills.

We have argued that these findings support the following theoretical conclusions. First, exclusivity inferences for words do not appear to be pragmatic in nature: they are unimpaired in children with pragmatic deficits, they are uncorrelated with social-communicative skills, and they do not pattern with exclusivity inferences for facts. Next, by 5 years of age, the mechanism that generates exclusivity inferences for words is, to some degree, domain specific: exclusivity inferences for words are stronger and less situationally-dependant than exclusivity inferences for facts and they are predicted by language-specific knowledge (vocabulary) but not social-cognitive ability. Finally, this domain-specific mechanism for exclusivity inferences could arise in one of two ways: it could be specific to the domain of language throughout ontogeny, or it could arise during development through the interaction of domain-general learning mechanisms and input that has an internal structure which gives rise to the relevant bias.

To fully evaluate these conclusions, we must look beyond the prior work comparing exclusivity for words and for facts. Two broader considerations seem particularly relevant.[9]

First, further research exploring the predictions of the pragmatic hypothesis suggests that children only make exclusivity inferences when they believe that two linguistic forms are conventionally used to express similar communicative intentions and the speaker knows this fact

[8] Of course this explanation leads to the question of how a child knows the kind of problem that she is confronted with. But since this question is likely to be troublesome for all theories, we put it aside for now.

[9] We thank Gil Diesendruck for suggesting these concerns.

(see e.g., Diesendruck, 2005; Diesendruck et al., 2010). While such evidence might appear difficult to reconcile with our data, or conclusions, we see several possible solutions. One could privilege the prior data and argue that exclusivity inferences are always pragmatic. On this view, our findings help to delineate the nature of those pragmatic skills (they are ones which are intact in high-functioning autism and are not closely correlated with the SCQ). The challenge for this account is to explain why words and facts pattern so differently in a task which does not require the inference that the form is conventional (see Section 4.3).

Alternately, one could argue that the studies in question fail to tap into the lexical mechanisms that produce exclusivity inferences because other cognitive processes may intervene, redirecting the input or overriding the output. For example, Diesendruck and colleagues (2010) found that preschoolers failed to make exclusivity inferences in a novelty task when the speaker had previously systematically mislabeled objects (e.g., calling bananas *apples*). The authors interpret this as evidence that exclusivity inferences are contingent on the listener's belief that speaker is respecting the principle of conventionality. Under the lexical theory, this data can be explained by positing that the lexical mechanism producing exclusivity inferences is simply not engaged in this task. The overt goal of this task, like all mutual exclusivity tasks, is to read the speakers referential intent (give him what he wants). Typically, our interpretation of referential intent is constrained by the meaning of an utterance, and so lexical processes are visible in the child's actions. But in the unreliable speaker studies the child is given ample evidence that the speaker's referential intentions are independent of linguistic forms. Thus she may solve the task by bypassing language comprehension (and the lexicon) entirely, and looking for clues to the speaker's intentions outside of the utterance (e.g., based on eye gaze or conjectures about the speaker's preferences). Because these other cues are presumably random with respect to the novelty of the objects, this should result in chance performance.[10]

Finally, in many of these studies, the pragmatic manipulations can also be characterized in lexical terms, and thus one could reframe the effects as evidence for a more refined domain-specific model of mutual exclusivity. For example, in an exclusivity task with preschoolers, Diesendruck (2005, Study 1) found that the form class of the novel nouns (common vs. proper) and the presence of the speaker when the first label was used interact to determine whether a new label will be interpreted contrastively. Within the pragmatic hypothesis this interaction is interpreted as evidence that conventionality applies to common nouns but not proper nouns. Under the lexical hypothesis, this interaction suggests that by 3 years of age the lexical mechanism of mutual exclusivity is restricted to common nouns; proper nouns pattern like facts and engage a less robust pragmatic process.[11] A similar account can be provided for the finding that in bilingual speakers, exclusivity inferences are present within a language, but fragile or absent between two languages (Au & Glusman, 1990; Merriman & Kutlesic, 1993). On the pragmatic hypothesis, this is seen as evidence that exclusivity inferences are limited to cases where the speaker can be assumed to be familiar with the conventional form. On the lexical hypothesis, these effects suggest that bilinguals only apply mutual exclusivity within the lexicon of a single language.[12]

A second argument that is sometimes made is that domain-specific accounts are, by their very nature, less satisfactory as explanations. One could argue that the claim that lexical exclusivity inferences arise because of a lexical constraint is simply rephrasing the problem rather than providing an answer. While this is true in one sense, it is, in that sense, equally true of the pragmatic account. Neither story, as currently told, provides a mechanistic account of how exclusivity arises in ontogenetic or phylogenetic time, or how it is implemented in real time. However, both accounts are compatible with a range of explanations on all of these time scales. Nevertheless, there is a fundamental and theoretically meaningful difference between the two theories, and thus a sense in which they are competing explanations. On the pragmatic account, all exclusivity inferences are side effects of the operation of general pragmatic machinery, and so, on this theory, the lexical exclusivity inference is a phenomenon, but not a natural kind. On the lexical constraints account, exclusivity inferences for words are subserved by mechanism that is specific to words. Thus, the assertion that lexical

[10] This proposal receives additional support from studies demonstrating that children: prefer to learn words from reliable speakers rather than unreliable ones; distinguish between the referential intentions and the meaning of the word; and fail to ascribe a stable meaning to a novel word when the speaker is ignorant (Jaswal & Neeley, 2006; Koenig, Clement, & Harris, 2004; Koenig & Woodward, 2010; Sabbagh & Shafman, 2009). These findings suggest that the machinery of lexical acquisition is not employed when it would be counterproductive.

[11] In the Diesendruck study, the syntactic form of the first and second noun are different, such that in the count noun condition the first object is labeled as a count noun ("the teega") while the later, referentially-ambiguous, word is a proper noun ("Moli"). Thus, children's successful performance in the count noun condition suggests that they take the existence of a generic term for an animal as evidence that future speakers will not refer to it using a proper name. This is problematic for the lexical hypothesis we propose above, but also for the pragmatic hypothesis (since a proper noun presumably encodes the communicative intention to refer to a unique individual, as an individual, while the common noun encodes the intention to refer to it as a member of a kind). One resolution to this mystery is to posit that children tend to perseverate in their interpretation of novel nouns such that the syntax of the initial labeling act overrides the syntax of the second label (either because the syntactic representation is primed, or because the initial labeling leads the child to construe the novel creatures as kinds of animals or nameable individuals).

[12] Study 2 of Diesendruck (2005) complicates this picture a bit. In this study, children interpret a label in one language (Hebrew) as exclusive with a prior label in another language (English), but only when the speaker is bilingual and was present during the initial labeling event. Diesendruck interprets this as evidence that the knowledge of the speaker determines whether a given linguistic convention applies. On the lexical constraints hypothesis, this pattern could be explained as follows: the lexical constraint of mutual exclusivity applies only within a single language, cross-linguistic exclusivity inferences are subserved by the same fragile pragmatic inference that accounts for the contrastive interpretation of facts, this pragmatic bias applies only within a single conversation and thus cannot apply when the speaker was unable to follow the prior discourse (monolingual present condition) or was absent during the critical conversation (monolingual and bilingual absent condition).

exclusivity inferences (as a phenomenon) arise because of a lexical constraint (a domain-specific process) is far from vacuous.

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