Learning and Processing Abstract Words and Concepts:

Insights from Typical and Atypical Development

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Abstract: The paper describes two plausible hypotheses concerning the learning of abstract words and concepts. According to a first hypothesis, children would learn abstract words by extracting co-occurrences among words in linguistic input, using for example, mechanisms as described by models of *Distributional Semantics*. According to a second hypothesis, children would exploit the fact that abstract words tend to have more emotional associations than concrete words to infer that they refer to internal/mental states. Each hypothesis makes specific predictions with regards to when and which abstract words are more likely to be learnt, also they make different predictions concerning the impact of developmental disorders. We start by providing a review of work characterising how abstract words and concepts are learnt in development, especially between the ages of 6 and 12. Second, we review some work from our group that test the two hypotheses above. This work investigates typically developing (TD) children and children with atypical development (Developmental Language Disorders (DLD) and Autism Spectrum Disorder (ASD) with and without language deficits). We conclude that the use of strategies based on emotional information, or on co-occurrences in language may play a role at different developmental stages.

Concrete entities exist in space-time and are independent of human minds/language; abstract entities, on the other hand, do not exist in space-time but their existence depends on human minds/language (Hale, 1988). “Concreteness”, therefore, indexes a basic ontological distinction, dividing entities into these two kinds. This ontological distinction is reflected in our epistemologies, and concreteness is arguably an organizing principle of semantic knowledge. A number of alternative theoretical proposals have been put forward with respect to differences in the way adults process concrete and abstract words and concepts, with a number of these hypotheses emphasising the role of embodied information (e.g., Borghi & Binkofski, 2014; Crutch & Ridgway, 2012; Kousta et al., 2011; Paivio, 2007; Schwanenflugel, 1991; see also Borghi et al., 2017, for a review). However, there are only few theoretical proposals that make explicit claims concerning *how* and *when* abstract words would be learnt.

In the paper, we spell out two of such proposals: the first arguing that statistical learning from linguistic input plays a key role, the second arguing for that the role of emotion in bootstrapping abstract learning is the most important. We then report on our empirical work that has mapped the developmental trajectory of abstract vocabulary learning (Ponari, Norbury & Vigliocco, 2017) and finally we summarise our studies with atypically developing children (both children with Developmental Language Disorder, DLD, and children with Autism Spectrum Disorder, ASD) that test some key assumptions of the hypotheses presented and provide novel insight into abstract word learning in typical and atypical development (Ponari, Norbury & Vigliocco, 2017; Vigliocco, Ponari & Norbury, 2017; Rotaru, Ponari, Lenci, Norbury & Vigliocco, under review, Norbury, Ponary and Vigliocco, under review). Here, we broadly define as abstract words those that refer to intangible referents, referring to states internal to the individual such as emotional and mental states, and we do not assume a categorical divide between emotion words and other abstract words (as instead assumed by others (e.g., Altarriba & Bauer, 2004)). Moreover, as in much of the literature, we operationalise “concrete” and “abstract” in terms of subjective ratings of concreteness (Brysbaert et al., 2014). These ratings provide a continuum between more abstract and more concrete words, not a dicotomic distinction.

1.Theories of Abstract Vocabulary Learning

Learning the meaning of words is one of the most complex and remarkable of human achievements. Children learn thousands of words quickly and efficiently, often without any formal training, and even in impoverished environments. Learning words is hard because even when the referent is present in the physical environment, it is rarely isolated in the visual scene (Medina, Snedeker, Trueswell & Gleitman, 2011). For example, imagine a child learning the word “cat”, while watching at a cat chasing a mouse in a kitchen with furniture, pots and pans, various foods and people. How would the child know to which of the many objects in view is the word “cat” referring to? This problem of referential ambiguity is challenging, but to make the situation worse, referents are not always present in the physical environment, either because they are spatially and/or temporally displaced (e.g., when talking about past or future events), or because they are abstract and have no material referent. Most theories of vocabulary acquisition focus on the mechanisms by which words referring to concrete concepts (i.e. objects, actions and other events that can be experienced with our senses and through our own actions) can be learnt; far less is known about how abstract concepts and words (which are not perceivable by the senses and refer to internal states) are learnt.

It has been argued that young children learn the meaning of concrete words such as “cat” or “run” by observing the statistical contingencies between the words and the objects, people and actions occurring in the physical environment. As such, children are actively engaged in making ‘word to world’ mappings (Yu and Smith, 2007; Gleitman, Cassidy, Nappa, Papafragou & Trueswell, 2005). In addition, such contingencies could be enhanced through the use of social communicative cues, such as eye-gaze, or pointing, through which caregiver actively directs attention to the correct referent (Baldwin, 1991) or actively isolates intended referents from the visual background by picking them up (Morse, Benitez, Belpaeme, Cangelosi & Smith, 2015).

Word meaning (for both concrete and abstract words) can also be derived from the linguistic context in which the word occurs; essentially, “you can know a word by the company it keeps” (Firth, 1957). Recent work has demonstrated how models of semantic memory, based on such distributional information, can predict a variety of semantic effects in adults and children (e.g., Andrews, Vigliocco & Vinson, 2009; Bruni, Tran & Baroni, 2014; Landauer & Dumais, 1997; Griffiths, Steyvers & Tenenbaum, 2007). Crucially, as abstract words and concepts, unlike concrete words, are independent from sensory and motor contingencies, it is plausible to assume that this distributional information may be more important for abstract than concrete words (see Vigliocco, Meteyard, Andrews & Kousta, 2009 for discussion).

Reliance on linguistic context to derive abstract meaning was also proposed by Gleitman (1990), who argued that in order to learn words such as verbs referring to psychological states (e.g., “think”, “believe”, “wonder” etc), young children need the additional information derived from the syntactic context in which the word is uttered (*Syntactic Bootstrapping*, Gleitman, 1990; Landau & Gleitman, 1985). Syntactic information provides crucial cues to meaning; for example, mental state verbs unambiguously take sentence complements as in: “I *think* that it will rain later today." “I *hope* that the trains won't be cancelled." According to the ‘syntactic bootstrapping’ hypothesis, words such as “think” and “hope” can only be learned when children achieve enough sophisticated linguistic knowledge to use sentence form to constrain meaning. In other words, once the children have learned a sufficient number of concrete words through word-to-world mapping, they can start acquiring abstract words through a process of (linguistic) sentence-to-world mappings.

It is important to note here that there are many differences between the syntactic bootstrapping hypothesis and the distributional hypothesis. First, the syntactic bootstrapping hypothesis applies to learning of specific aspects of meaning (those that can be derived from argument structure) from syntactic structure in early childhood, whereas according to the distributional hypothesis, *all* meanings can be inferred from co-occurrence-based statistical information from language input. It is also worth noting that distributional views do not usually take into account sequential and syntactic information (see Andrews & Vigliocco, 2010 for one exception) and they are usually referred to as “bags of words” approaches. Furthermore, linguistic information is thought to be critical early in development according to the syntactic bootstrapping hypothesis, whereas, according to the distributional hypothesis, it would be used especially later on in development (as there would need to be sufficient experience with language to allow for extracting the correct statistics). Thus, the distributional hypothesis predicts that abstract words will be acquired later in development. Crucially, however, both hypotheses assume that learning (at least some) abstract words is based on linguistic information and therefore, if language development is delayed, abstract word learning will be disproportionately impaired relative to concrete words, because concrete words rely less on linguistic context and more on integrating spoken utterances with the immediate environment.

These predictions find some support from studies investigating the neural systems underscoring abstract words processing. Abstract processing has been associated with higher activation in left hemispheric areas involved in linguistic processing/verbal semantics such as the left inferior frontal and superior temporal cortex (e.g., Hoffman et al., 2015, see Binder et al., 2009 and Wang et al., 2010 for reviews and meta-analyses).

As an alternative, Kousta, Vigliocco, Vinson, Andrews and Del Campo (2011) proposed that affective information plays a role in abstract word learning. Their hypothesis concerning word learning stems from results of lexical processing experiments with adults. First, they showed that once all lexical factors contributing to speed of word recognition are controlled (including imageability), abstract words are processed faster than concrete words. They then showed how this reversal of concreteness effect in adults can be accounted for on the basis of greater affective association of abstract, relative to concrete words. There is, in fact, a general tendency for abstract concepts to be more affectively loaded than concrete concepts (Kousta et al., 2011; Vigliocco et al., 2014). Such a general tendency is also present once we exclude from analysis those abstract words denoting emotion (see Vigliocco et al., 2014). It has been shown that affectively loaded (i.e., valenced) words are processed faster than neutral words (Kousta, Vinson & Vigliocco, 2009; Vinson, Ponari & Vigliocco, 2014); thus, the reported advantage for abstract word processing (once all other factors that favour concrete words - such as familiarity and imageability - are controlled), has been interpreted as an effect of valence (Kousta et al., 2011). These behavioural findings have since been complemented by imaging results showing the engagement of brain networks associated with processing emotion in processing abstract, but not concrete, words (Vigliocco et al., 2014), once factors such as word familiarity and imageability are taken into account.

The central tenet of Kousta et al's (2011) hypothesis is that abstract words and concepts are *grounded* in our emotional experience. In particular, while words referring to concrete objects and actions would be learnt primarily by associating sensory-motor experience with the word, learning of abstract words would be supported by their associations with emotional states. This association with emotional states would allow children to grasp the ontological distinction between concepts grounded in the physical environment (concrete) and those grounded in our internal states (abstract), thereby bootstrapping the development of abstract knowledge. Such a close link with the affective system would then impact on processing during adulthood (Kousta et al., 2011; Vigliocco, et al., 2009).

It is important to note that these hypotheses are not mutually exclusive: both linguistic and emotional information are likely to contribute to the acquisition of abstract vocabulary. A likely scenario is one in which while emotional grounding plays a key role early in development. However, in order to learn the specific meaning of each abstract word, emotion is clearly insufficient and other types of information, including linguistic information, become essential.

To summarise, distributional models of semantics would predict that learning abstract words and concepts requires substantial linguistic experience (because abstract words tend to be less frequent and acquired later) and that their semantic representations could not benefit from embodied properties of meaning. A somewhat related specific developmental hypothesis is the "syntactic bootstrapping" hypothesis, arguing that linguistic experience during early childhood is critical, at least for some abstract words (primarily verbs) for which important aspects of meaning can be extracted from their argument structure (e.g., psychological verbs). Finally, according to our proposal linking abstract and emotional processing, early acquired abstract words would be emotionally valenced and emotion could bootstrap early acquisition of abstract vocabulary. We have explored the predictions from these different accounts in several studies which are summarised below.

2. Abstract vocabulary in typical development

Abstract words are acquired later in development (Kousta, Vigliocco, Vinson, Andrews & Del Campo, 2011; Ponari, Norbury & Vigliocco, 2017; Schwanenflugel, 1991).

Crucially, the majority of first words in a child's vocabulary are concrete nouns and, consistent with the syntactic bootstrapping hypothesis, children at this stage produce syntactically simple utterances (e.g. one-word utterances). However, abstract words denoting emotional states emerge early in language development, at around 20 months of age, and their rate of acquisition increases rapidly in the third year of life (Bretherton & Beeghly, 1982; Wellman, Harris, Banerjee, & Sinclair, 1995). For instance, Ridgeway, Waters, & Kuczaj (1985) report that 76.7% of children aged 18-23 months have acquired the meaning of the words "good" and "happy".

When children start producing short sentences, thus showing the first rudiments of syntactic knowledge, the rate at which new vocabulary is learnt increases dramatically (Gleitman et al., 2005). Nevertheless, early studies of children's language production (Brown, 1957, reported in Schwanenflugel, 1991) suggested that 75% of the words most frequently produced by school-aged children (6-12 years of age) are concrete; in contrast, only 28% of the words used most commonly by adults are concrete. Schwanenflugel (1991) further reported that, while 6-year-old children have already mastered the majority of concrete words most frequently used by adults, it is not until adolescence that children have mastered the majority of abstract words used by adults. These facts align well with the idea that a large amount of linguistic (and syntactically complex) input is necessary to extract meaning for abstract words.

Ponari, Norbury and Vigliocco (2017) provide initial insight into how and when abstract words are learnt in early school years. In a first study, they conducted a corpus analysis of ratings provided by adult speakers for over 13,000 English words, and assessed the relation between ratings of age-of-acquisition, concreteness and valence, in order to estimate the number of abstract words thought to be learned during childhood and their emotional grounding.

This study employed a set of 13,266 words. Each word was characterised in term of ratings for age-of-acquisition (age at which given words are learnt, from Kuperman et al., 2012), concreteness (the extent to which a given word refers to concrete referents or not, from Brysbaert et al., 2014), and valence (the extent to which a given word has positive, negative or neutral emotional connotations, from Warriner et al., 2013).

This analysis, illustrated in Figure 1, documented for the first time the development of abstract vocabulary in childhood, from being less than 10% of the total vocabulary of children aged 4, to more than 40% by the age of 12. Especially interesting is that the rate at which abstract vocabulary is acquired appears to change at about 8.5 years of age. Consistent with the strong correlation between emotion and concreteness (Kousta et al., 2011; Vigliocco et al., 2014), the steep increase in abstract word knowledge up to an age of 8.5 resembles the sharp increase in knowledge of emotion words reported by Baron-Cohen et al. (2010, for British children) and by Li and Yu (2015, for Chinese children) up to 9 years of age.

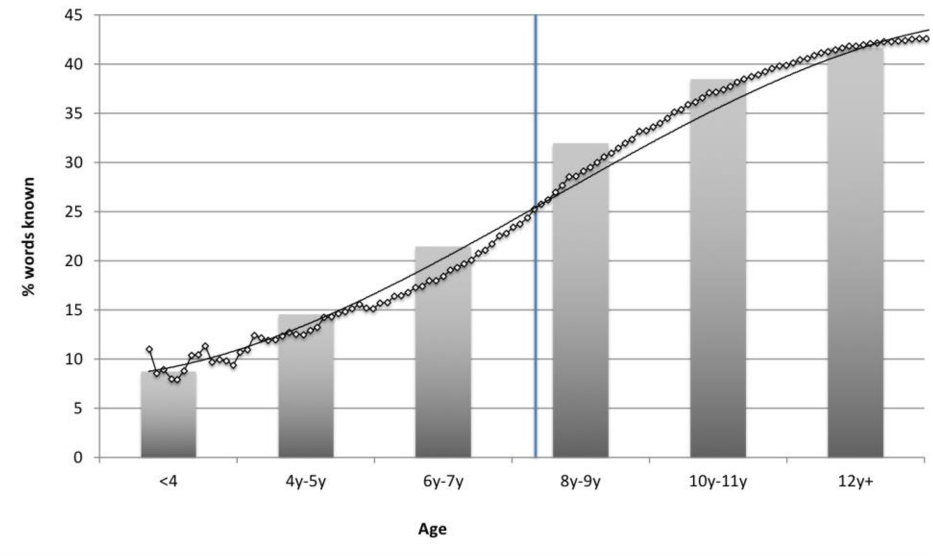

Figure 1: Percent of known abstract words (over total vocabulary) at different ages computed on age-of-acquisition norms (from Ponari, Norbury & Vigliocco, 2017; with permission)

Ponari et al (2017), also found that, when learning abstract words, valenced words (both positive and negative) appear to be learnt earlier than neutral words. For concrete words, we observed that only positively valenced words are learnt early (see Figure 2). The finding that the first abstract words acquired are valenced (both positive and negative) provides support for the hypothesis that emotion may bootstrap the acquisition of abstract words. The engagement of the affective system may be critical in enabling children to ground what is abstract to our internal feelings (Kousta et al., 2011; Vigliocco et al., 2014). Importantly, this is not to say that only abstract words are linked to valence; we also observed that for concrete words, positive words are learnt earlier. For concrete words, however, emotion may not be such a critical cue for grounding, given that for these words, referents exist in the physical world.

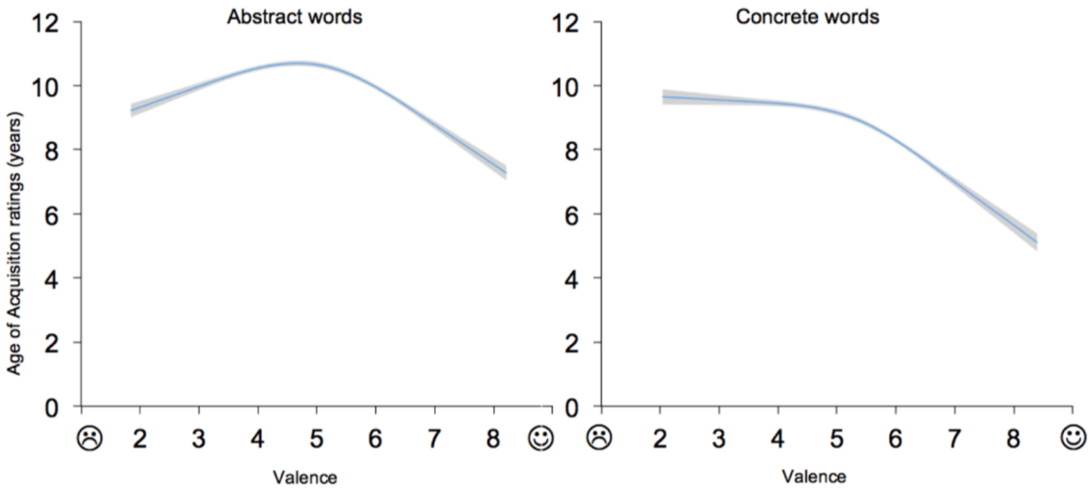

Figure 2: Valence as predictor of age-of-acquisition for abstract and concrete words (from Ponari, Norbury & Vigliocco, 2017; with permission)

While these results suggest a clear difference in the role of emotion in the learning of concrete and abstract words, of course they are solely based on ratings by adults. In a second study with 6-11 years old children, Ponari et al. (2017) assessed the role of emotion in the processing of abstract and concrete words using a lexical decision task. We used lexical decision in continuity with studies with adults where it is well established that semantic effects are visible in the task. Just as in the previous study, valence ratings for the words used were taken from adults' norms. However, it is interesting to note that in unpublished work we found that the correlation between children's (N = 14, mean age 11.7 years) and adults' valence ratings (from Warriner et al., 2013) was extremely high (r = .939).

They found that valence had a differential effect for abstract and concrete words as well as developmental changes. Valence affected accuracy rates for abstract words differently at different ages (see Figure 3): children aged 8-9 overall performed better with valenced (especially positive) abstract than neutral abstract words and with neutral concrete than valenced concrete words. Children aged 10-11 also showed an advantage for abstract positive words when compared to negative words but no difference between abstract (positive and negative) words compared to neutral. For concrete words this age group showed an advantage for neutral over valenced words. Accuracy rates were overall much lower for children aged 6-7 and no significant effect was observed in this age group. These results suggest that children know that concrete words tend to be neutral and that abstract words tend to be valenced, at least at an age (8-9) in which their repertoire of abstract words is fast growing.

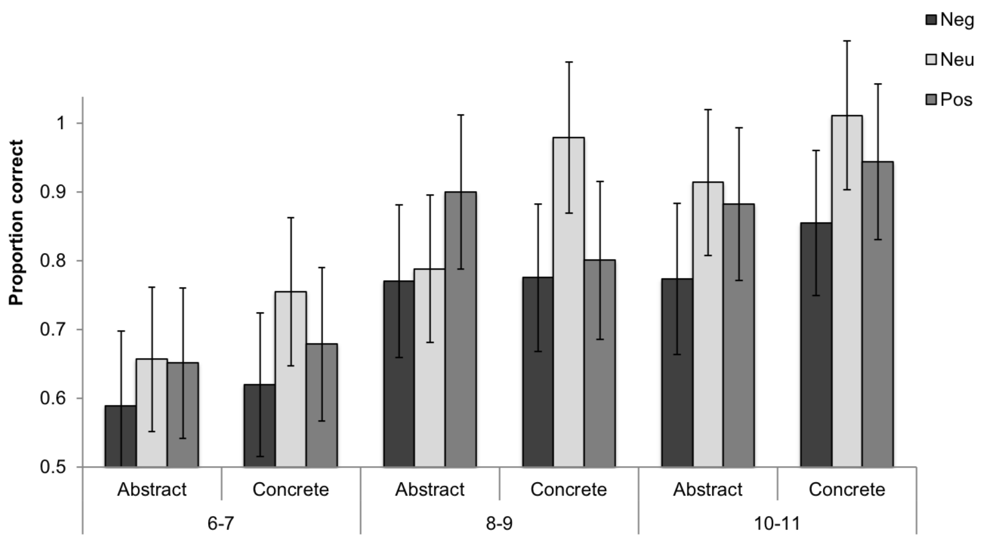

Figure 3: Accuracy at a lexical decision task for positive, negative and neutral abstract and concrete words (from Ponari, Norbury & Vigliocco, 2017)

What do these results tell us about the theories we discussed above? Results show that emotional associations of words have a greater role in the acquisition of abstract, relative to concrete words (age of acquisition norms), and that children aged 8-9 in contrast to children aged 10-11 are better at recognising abstract valenced words rather than neutral consistent with the hypothesis by Kousta, Vigliocco et al. according to which emotion could bootstrap abstract knowledge.

This is not to say that language does not play any role in the learning of abstract words and associated concepts across childhood; it simply indicates that it cannot be the only type of information used. It is important to note here that emotion does not appear to have any privileged role in acquiring abstract vocabulary after the age of 9 (as shown in our auditory lexical decision study). It is likely that by this age, strategies that are not grounded on emotion are being used more. It is also noteworthy that this is also the age at which the rate of abstract word learning appears to slow down, as shown by the analyses of lexical databases, suggesting that emotional valence is not as effective after the age of 9. Such findings suggest that emotion might be especially relevant to establish the ontological distinction between concepts that refer to entities in the world outside (concrete) and internal states (abstract): once this distinction is established, and as vocabulary increases, valence alone does not allow for fine grain discrimination between abstract words with similar meaning. At this point, the child has a wider vocabulary and linguistic competence and therefore can exploit effectively the correlational patterns in discourse in order to extrapolate fine-grained meaning distinctions. At the age of 9, reading proficiency has also developed sufficiently to allow for acquisition of vocabulary from written texts thus favouring even more the use of distributional information in language.

3. Abstract vocabulary in atypical development

Distributional theories, as well as syntactic bootstrapping, predict that abstract words should be especially challenging to acquire for children with Developmental Language

Disorder (DLD). DLD is a common neurodevelopmental disorder affecting approximately 7.5% of children at school entry (Tomblin et al. 1997). Children with DLD have language abilities significantly below expectations for age in the absence of obvious social (i.e. extreme deprivation), sensory (i.e. hearing loss) or neurodevelopmental (i.e. head injury or known syndrome) explanations. While there is limited consensus regarding definitive inclusion criteria, children with DLD typically present with severe deficits in morphosyntax and other aspects of grammar (Rice, 2013), crucially accompanied by vocabulary that is heavily reduced when compared with typically-developing peers (McGregor, Oleson, Bahnsen & Duff, 2013). Previous research has shown that children with DLD do not use correlational information to the same extent as their typically developing (TD) peers (Evans, Saffran & Robe-Torres, 2009) and moreover they have difficulties using syntactic bootstrapping to learn new words (Shulman & Guberman, 2007). Assuming these mechanisms are more important in the learning of abstract vocabulary, children with DLD should exhibit a marked deficit in abstract vocabulary, relative to their peers. DLD also has a high incidence in Autism Spectrum Disorder (ASD) and it has been suggested that there may be distinct language phenotypes within ASD (Tager-Flusberg & Joseph, 2003), in which as many as 50% of cognitively able children with ASD present with clinically significant language impairments that are similar in kind and severity to those seen in children with DLD (Kjelgaard & Tager-Flusberg, 2001; Loucas et al. 2008). Vigliocco, Ponari and Norbury (2017), Rotaru, Ponari, Lenci, Norbury & Vigliocco (under review) and Norbury, Ponari & Vigliocco (under review) investigated implicit and explicit knowledge of abstract and concrete words in children with DLD and children with ASD (with and without language impairments). Auditory lexical decision was used to test implicit knowledge, while verbal definitions were used to test explicit knowledge. We considered accuracy as dependent variable for the auditory lexical decision task, whereas, we used definition scores (from 0 if the definition was completely incorrect to 4 if definition was fully correct) for the definition task. We only focused on accuracy data because, given the high constraints in selecting stimuli, we could not control for first phonemes or for uniqueness point, both of which are known to affect RTs in auditory lexical decision tasks (see Goldinger, 1996). We used a lexical decision task and a definition task to tap both into more implicit processing of semantic information (lexical decision) as well as into children's explicit knowledge of these words (definitions). Definition tasks are also very common to clinical practice.

Vigliocco et al (2017) and Rotaru, Ponari, Norbury, Lenci & Vigliocco (in prep) compared the performance of 18 children with DLD to both a group of typically developing children matched for age and a group of younger, typically developing children matched on receptive vocabulary. Both distributional accounts and syntactic bootstrapping predict that children with DLD will have disproportionate difficulties with abstract words. DLD children who participated to this study were aged between 10-12. While it is the case that syntactic bootstrapping has been suggested as a mechanism at play much earlier on (in toddler years), we reasoned that if such bootstrapping is unsuccessful (as we assume would be in children with DLD), consequences should be apparent later on as well. Moreover, we did not expect to observe any effect of valence at this age on the basis of our results with TD children.

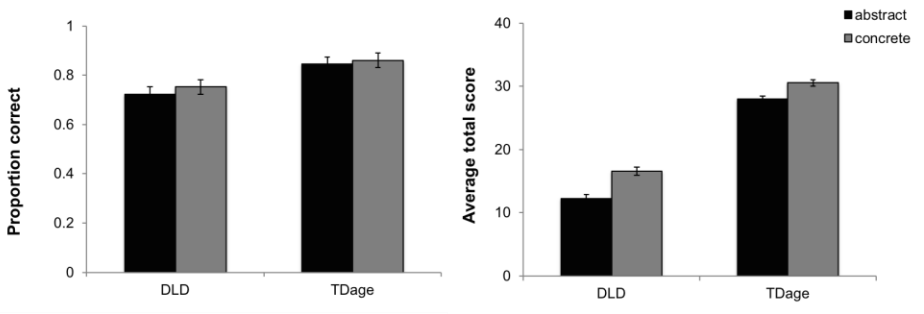

Figure 4: Comparison between children with DLD and typically developing children of the same age. (a) Proportions of correct recognitions; (b) average total definition score (from Vigliocco, Ponari & Norbury, 2017)

We found that children with DLD did not show a disproportionate disadvantage for abstract words, in both lexical decision and in definition tasks. Rather, they showed a general disadvantage in comparison to their TD peers matched for age for all words (see Figure 4, a and b, for lexical decision and definitions, respectively). As sample sizes are necessarily small, Vigliocco et al. followed up the group analyses with analyses typical of case-series studies in neuropsychology and further confirmed that the lack of difference between concrete and abstract words was reliable on an individual basis.

Norbury, Ponari and Vigliocco (under review) investigated learning of abstract concepts and words in a different group of children, those with ASD, who may or not have associated language impairment. ASD is a neurodevelopmental disorder characterised by deficits in social interaction and communication, as well as a restricted repertoire of interests and behaviours (American Psychiatric Association, 2013). Deficits in social and emotional processing are also characteristic of individuals with ASD, yet clinical manifestation of these deficits may be variable. Understanding and use of language referring to internal states has long been reported to be deficient in children with ASD (cf. Tager-Flusberg, 1992), however, studies that have carefully matched ASD and TD groups for level of language ability have found little difference between groups regarding the use of mental and emotional state terms in spontaneous discourse (Bang, Burns & Nadig, 2013). It is in fact the case that children with ASD are highly heterogeneous with respect to language skills, with up to 50% of the children with ASD also showing a phenotype similar to that of children with DLD (Kjelgaard & Tager-Flusberg, 2001; Loucas et al. 2008). The question addressed by Norbury et al (under review), therefore, was whether the social/emotional deficit exhibited by children with ASD would lead to a disproportionate impairment in their knowledge of valenced abstract words, or whether, instead, once language impairment is accounted for, they would perform as their TD peers.

Figure 5a and b, reports the results from lexical decision and the definition task for the children with ASD, divided into those children with associated language impairment

(ALI) and those without language impairment (ALN). As is clear from the figure, children with ASD whose language is within the normal range are undistinguishable from their typically developing peers whereas those children with ASD and LI show the same general deficit (across both concrete and abstract vocabulary) as children with LI without ASD. This suggests that whatever causes the social/emotional impairment in autism does not disproportionately affect the acquisition of abstract concepts and words.

Insert Figure 5 about here

There are important limitations to the studies described above, however, that need to be kept in mind. In general, it is the case that the samples used are relatively small, and children were tested on a relatively small number of words. Moreover, with regards to the study with DLD children, we did not test children's syntactic competence, which is critical in order to make stronger claims concerning the syntactic bootstrapping hypothesis, nor did we tested their ability to use statistical information (in verbal and crucially non-verbal domains), which is critical in order to establish how well they can use co-occurrences in text. With regards to the children with ASD, it has been argued that emotional deficits are not a general feature of autism but are more closely linked to a sub-group of autistic children, those who suffers of alexithymia which often co-occur with autism (Bird & Cook, 2013). Children included in the study were not screened for co-occurring alexithymia.

Conclusions

The work we have reviewed here is the first, to our knowledge, to investigate the development of abstract vocabulary combining data from databases, typically developing children, children with language impairment and autism spectrum disorder. The results we have summarised provide a number of important constraints on theories of abstract development. For typical development, Ponari et al. (2017) reported a role for valence in the acquisition of abstract vocabulary, especially positive valence and particularly in the earlier stages of language acquisition. In their lexical database analyses, they further found that abstract vocabulary steeply increases up to around 8-9 years of age, after which the rate of abstract word learning slows down. Ages 8-9 years is also the age at which, in our lexical decision study, children seem to benefit the most from valence. Baron-Cohen et al. (2010) investigated the development of emotion vocabulary in children aged 4-16 via parent or teacher report and Li & Yu (2015) replicated the study with Chinese speaking children aged 2-13. Words included in these studies (336 in Baron-Cohen et al., and 363 in the Li & Yu study) "described mental state[s] with an emotional dimension", Baron-Cohen et al., 2010, p. 2; examples were *furious* or *relief*), therefore they were all abstract words in addition to being emotional. In line with the results we reported here, they also found a sharp increase in the number of abstract words reportedly known by children between the ages of 7-8 and 9-10. For atypical development, the results reported by Rotaru et al. (under review) and Norbury et al (under review) indicate that neither language impairments, nor autism lead to specific deficits in learning abstract words and concepts.

We have described above two main theoretical views on how abstract words could be learnt. According to one view, the ability to extract semantic information from language would be especially critical for learning abstract words and concepts. One potential mechanism underlying language-based vocabulary acquisition, that would benefit especially abstract words, would be the extraction of correlational patterns in discourse and texts. On the basis of the linguistic contexts in which a word is used, children could make inferences about their meaning, as argued by distributional theories of semantics (Landauer & Dumais, 1997, Griffiths, Steyvers & Tenenbaum, 2007; see discussion in Andrews et al, 2009). Of course, for such mechanisms to be effective, children must have acquired ample linguistic competence and vocabulary. Language is further used in an explicit manner when carers or teachers tell children the definition of abstract words. Our results with TD children suggest that such mechanism may be used after the age of 10. By this age, children would have had the necessary experience with diverse linguistic contexts to extract co-occurrence information, possibly especially from written text. However, Rotaru et al (under review) did not find a greater impairment in abstract than concrete vocabulary for children with DLD despite the fact that children with DLD do not have the same vocabulary competence as typically developing children (McGregor et al., 2013), and they may not take advantage of correlational information to the same extent as their typically developing peers (Evans, Saffran & Robe-Torres, 2009). The same pattern of generalised vocabulary impairment for concrete and abstract words is reported by Norbury et al. (under review) for children whose language impairment is co-morbid with ASD. Thus, although statistical linguistic information contributes to the development of abstract knowledge, it cannot be the only type of information on which this knowledge is based. Rather, as argued by some this information can play an important role in learning vocabulary across the board for both concrete and abstract domains (e.g., Andrews et al., 2009; Jones & Johns, 2012).

The other theoretical view we have addressed here is one in which learning abstract words and concepts would, at least in the earlier stages of acquisition, take advantage of the strong association between abstractness and emotional valence. Emotional valence could support the establishment of the distinction between concrete and abstract domains of knowledge; while concrete words would refer to observable entities and actions that we can experience with our senses and act upon ourselves, abstract words would refer to internal states of self and others that trigger embodied emotional reactions and experiences, thus bootstrap the system. These emotional reactions could come about from interactions with caregivers in which children would associate words being heard with emotions being expressed by the caregivers or by the child themselves thus emphasising the role of communicative social interaction, along the lines proposed by recent social-cognitive theories of lexical development (e.g., Tomasello, 2010).

Emotional associations of words seem to have a role in the learning (abstract valenced words are learnt earlier) and processing (abstract valenced words are recognised more accurately), relative to concrete words especially up to age 9 in TD children compatibly with the emotional bootstrapping view. However, children with ASD do not show abnormal performance with abstract nor with valenced words in our study. As discussed above, this latter result may be a consequence of different mechanisms underscoring the social and emotional deficits in ASD and the social communicative interactions considered to be critical in abstract development. However, we cannot exclude, only on the basis of these findings, that emotional bootstrapping might not provide the primary mechanism for abstract vocabulary acquisition, as argued instead by Vigliocco et al., (2009).

Thus, the main conclusions we can draw are that emotion may provide building blocks especially for early acquisition of abstract vocabulary. But, clearly, cannot explain how children develop rich abstract vocabularies with fine-grained distinctions among words. Distributional linguistic information may also play an important role especially later on, but such a role is not special for abstract vocabulary as we have seen that DLD children do not show any disproportionate impairment with abstract words. Our results leave open the possibility that other mechanisms are necessary for the development of abstract knowledge. Some theories of abstract representation based on neuropsychological evidence have stressed the role of frontal cortex (especially the left ventrolateral prefrontal cortex) in the processing of abstract concepts (Hoffman & al., 2015; Shallice & Cooper, 2013). In the account by Shallice and Cooper (2013), abstract concepts would be qualitatively different from concrete ones in that their processing would depend on more complex logical operations, including unification, recursion and argument filling (such operations have been argued to be at play in children understanding of syntactic/semantic distinctions such as those applied to count vs. mass nouns, Zanini, Benavides-Varela, Lorusso et al., 217). These operations would crucially depend on frontal regions whose maturation would occur throughout childhood (Gogtay et al., 2004). It remains for future research to explore the link between frontal lobe maturation, development of logical operations and learning of abstract concepts.

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Figure Captions:

Figure 1: Percent of known abstract words (over total vocabulary) at different ages computed on age-of-acquisition norms (from Ponari, Norbury & Vigliocco, 2017 with permission)

Figure 2: Valence as predictor of age of acquisition for abstract and concrete words (median split on concreteness ratings), reproduced with permission from Ponari, Norbury & Vigliocco (2017)

Figure 3: Accuracy in a lexical decision task for positive, negative and neutral concrete and abstract words (from Ponari, Norbury & Vigliocco, 2017)

Figure 4: Comparison between children with DLD and typically developing children of the same age. a) Proportions of correct recognitions; b) definition scores (max = 4) (from Vigliocco, Ponari & Norbury, 2017)

Figure 5: (a) Accuracy in a lexical decision task for concrete and abstract words for children with ASD (language impaired, ALI and language normal, ALN) and children without ASD (Language Impaired, LI and Typically Developing, TD). (b) Definition scores for concrete and abstract words for ASD and Comparison group (from Norbury, Ponari & Vigliocco, under review).

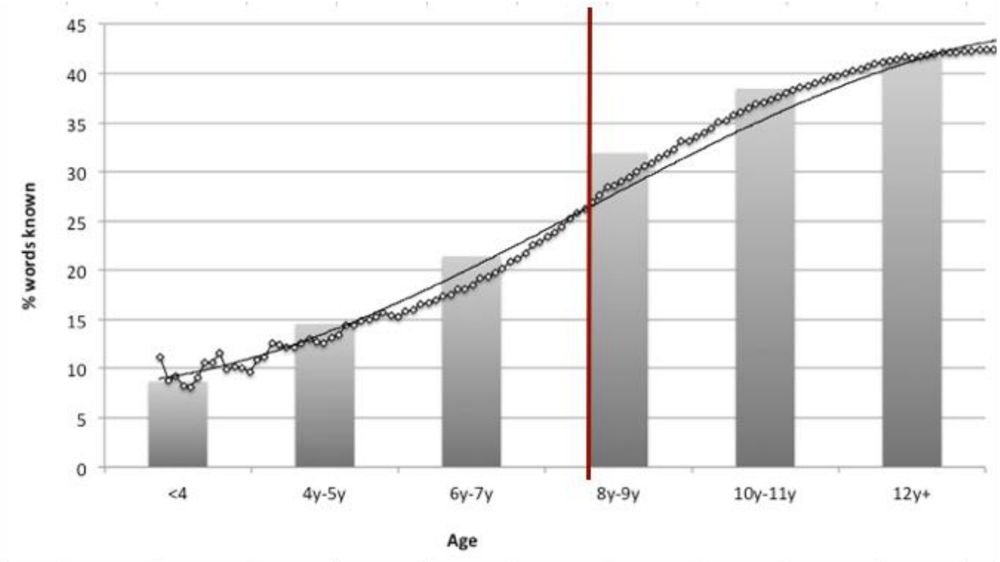
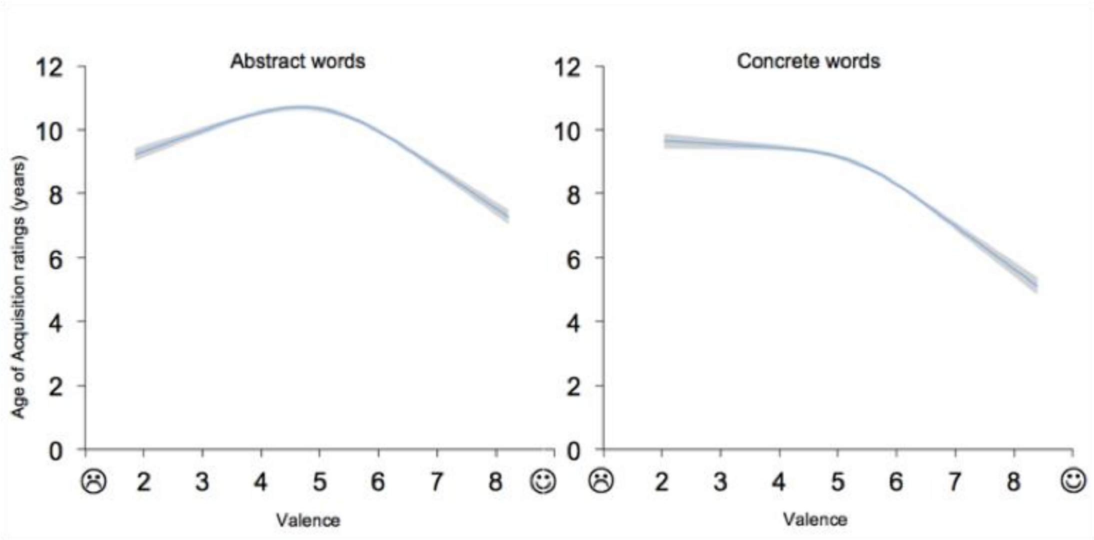


Figure 1: Percentage of abstract words (over total words) known at each age, from <4 to 12+ years (from Ponari, Norbury & Vigliocco, 2017). The histogram indicates the average percentage of abstract words known at different age groups. The dots indicate the percentage of abstract words known at age intervals = 0.1 years, from 2.7 to 14 years. The curve indicates the polynomial function used to calculate the inflection point (vertical line).



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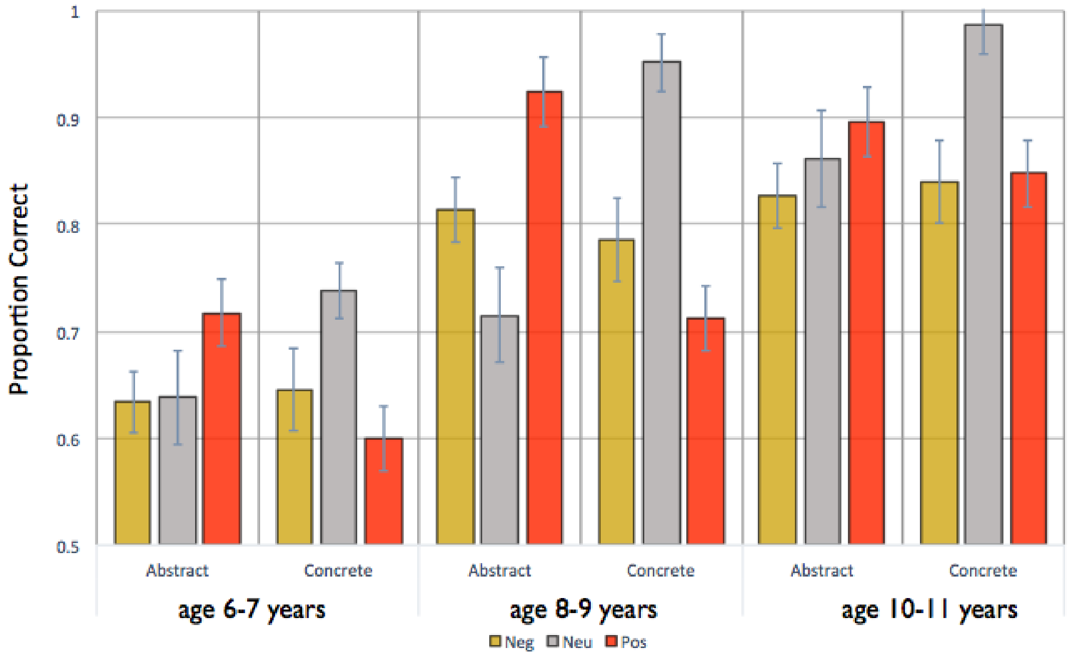

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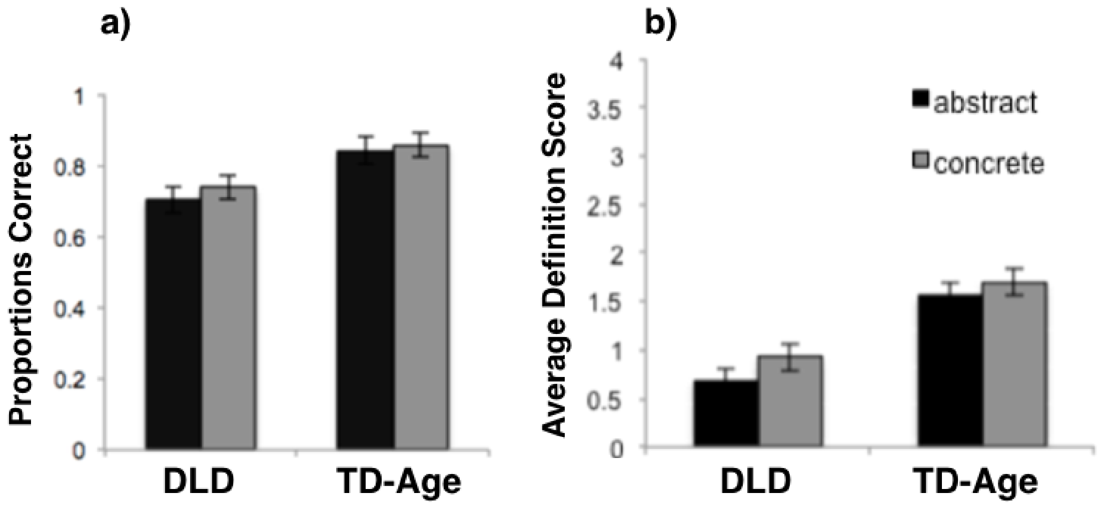

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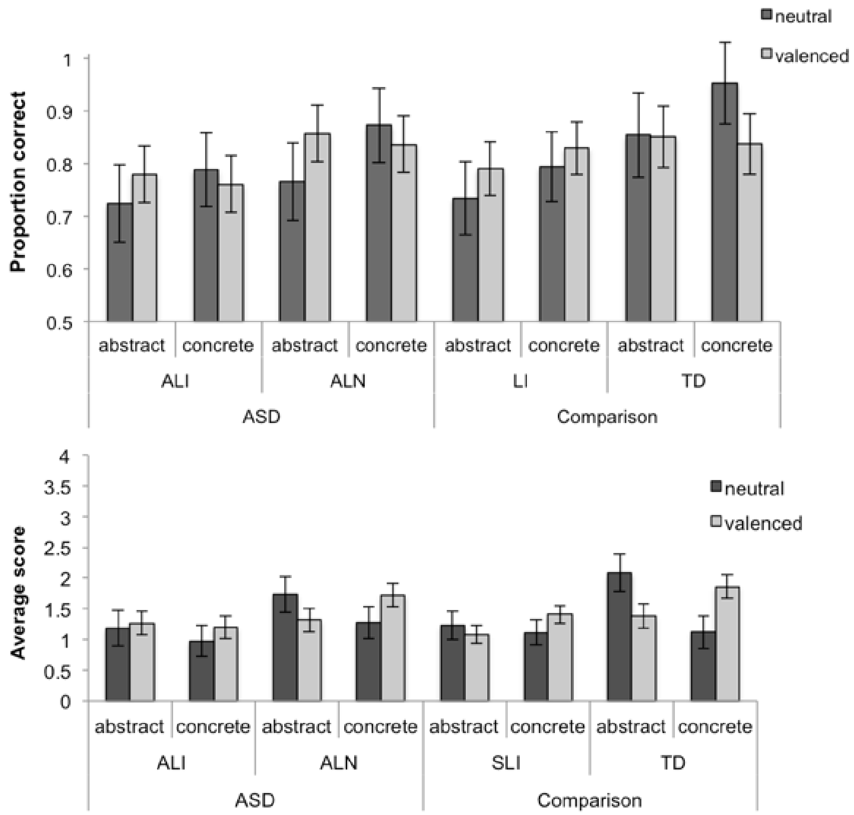

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