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A Formal Semantic Analysis of Autistic Language: The Quantification Hypothesis

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A FORMAL SEMANTIC ANALYSIS OF AUTISTIC LANGUAGE: THE QUANTIFICATION HYPOTHESIS

by

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ABSTRACT

A FORMAL SEMANTIC ANALYSIS OF AUTISTIC LANGUAGE: THE QUANTIFICATION HYPOTHESIS

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Autism is characterized by language dysfunction ranging from mild and peculiar language usage to a total lack of expressive language function. These language oddities are manifest in the form of phonological, morphological, syntactic, semantic, and pragmatic/behavioral dysfunction. Research suggests that the autistic language deficit is focal—dealing with a specific area of language processing; however, previous research has failed to identify this language enigma. This thesis demonstrates a novel approach to the problem, showing that the autistic language deficit is tied to a particular aspect of language processing—quantification. Quantification is defined and explained in the context of autistic language and behavior.

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CHAPTER 1: PREVIOUS WORK ON AUTISM

Autism is characterized by language dysfunction ranging from mild and peculiar language usage to a total lack of expressive language function. These language oddities are manifest in the form of phonological, morphological, syntactic, semantic, and pragmatic/behavioral dysfunction. Research suggests that the autistic language deficit is focal—dealing with a specific area of language processing; however, previous research has failed to identify what that area of processing might be. This thesis demonstrates a novel approach to the problem, showing that the autistic language deficit is tied to a particular aspect of language processing. This chapter reviews major contributions to the study of autistic language and sets the framework for a new approach to autistic language, which I present in Chapter 2.

1.1. Phonological and sound processing. Autistic children exhibit marked peculiarities with respect to sound processing and production. These children are remarkably sensitive to acoustic stimuli (Sigman & Capps 1996:161-163). Additionally, they have great difficulty developing speech; in fact, many autistic children are never able to acquire meaningful acoustic production (Bosch 1970:123, 136). They have a particular problem with monotonic prosody (Lamers & Hall 2003; Shriberg, et al. 2001; Ramberg, et al. 1996) and intonation (Happé 1995). For example, Shriberg, et al. (2001) demonstrate that autistic subjects have a difficult time using prosody to distinguish between the verbal and nominal forms of 'present' (pre-'sent and 'pre-sent, respectively). Prosody and intonation are also important to correctly understanding grammatical information: many languages use prosodic contours to indicate the focus of an utterance. For example, 'John hit Joe' can have three general interpretations depending on which word is stressed (as indicated by a relatively large pitch change (ΔP) when the word is uttered). If the speaker emphasizes 'John' (agent focus), then she generally does so on the presupposition that the hearer questions the identity of the agent of an action. Likewise, event-focused and patient-focused prosody answer questions concerning the nature of the event and the identity of the patient, respectively. This is reflected in (1.1), where the word in all caps is emphasized with a large and rapid rise and fall in pitch.

(1.1a) JOHN hit Joe (subject focus)
(1.1b) John HIT Joe (event focus)
(1.1c) John hit JOE (object focus)

Autistic phonology is also characterized by echolalia (Dobbinson, et al 2003; Prizant 1983; Prizant & Duchan 1981), which is 'the mechanical and meaningless repetition of a word or word group just spoken by another person' (Fay & Schuler 1980). For example, when a parent says 'John is a good boy', an autistic child might respond with 'good boy'. This is consistent with the behavior of autistic subjects at practically any age (Prizant 1983). In the movie *Rainman*, Dustin Hoffman plays an autistic man (Ray) with remarkable abilities (a savant), who repeats the Abbott and Costello routine 'Who's on First?', but is unable to grasp the humor, and has no particular reason for restating the routine.

Foxton, et al. (2003) test the weak central coherence theory of autism (inability to unify the parts of stimulus into a single conception) by analyzing the auditory processing of 15 autistic and Asperger's syndrome subjects against 15 control participants. Subjects were administered auditory tests. In the first, they were required to determine if two tones were the same or different based on the patterns of rising and falling pitch. For this task, same patterns are totally identical and different patterns occur when one of the notes is changes by a magnitude of two.[1]

In the second, the subjects were given the same tone sequence as before, except that it was transposed to a half-octave higher pitch (this test measured local pitch inference). In other words, the notes are identical except there is a shift (up or down) by one-half octave for the entire sequence. A different sequence for this test pattern of rising and falling from note to note is different than the standard pattern.

The third test combined local pitch inference with timing inference. For this test, each tone sequence was followed by either a falling or rising pitch contour (which may or may not be the same contour as the initial tone sequence), and the subjects were again asked to discriminate different pitches. The sequences and contour patterns are identical, but the exact points of rising and falling differ. 'For example, the pitch directions in the first sequence might follow the series "up-down-down-down", while for the second sequence the pitch directions might follow the series "up-up-up-down".

So both sequences rise and then fall in pitch, although the relative time points of these changes do not match.' Different sequences, however, have different contour configurations. For example, one contour would rise, then fall in pitch, but a different sequence would fall, then rise in pitch.

The results showed that subjects with autism were actually better at discriminating pitch changes in the task testing local pitch inference and timing inference. Foxton, et al. (2003) attribute this difference to the tendency for a control subject to combine local auditory details, which indicates the ability to draw global inferences from local information. The marked differences in the study groups points out autistic subjects' inability to make such global inferences.

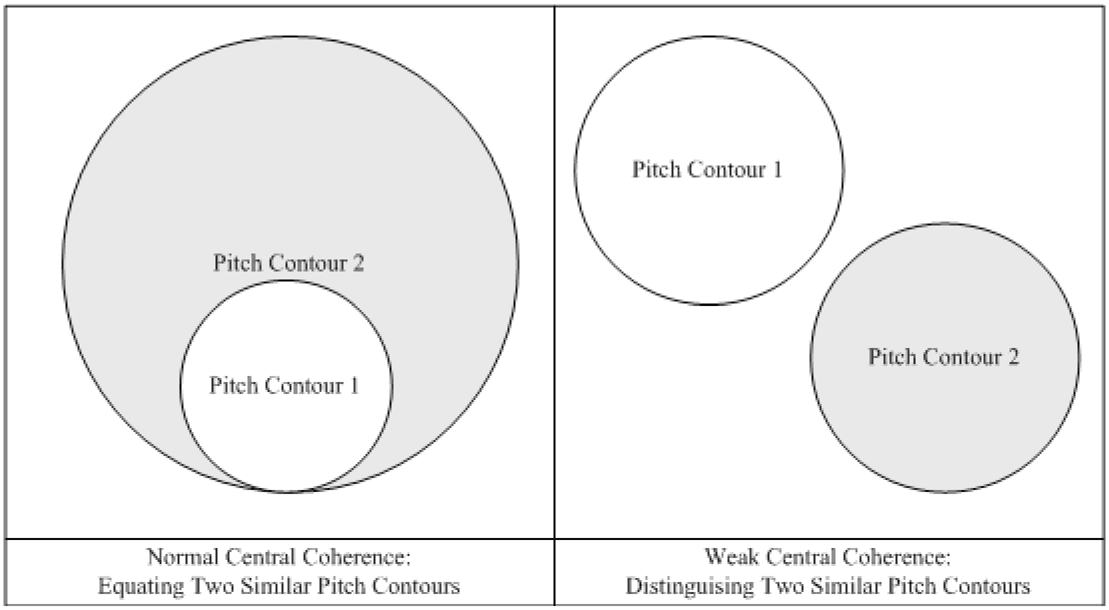


Figure 1.1. The set distinction between normal and weak central coherence.

Figure 1.1 shows the distinction between normal and weak central coherence with respect to pitch contours—autistic subjects don't group stimuli into sets; normal people do.

Shriberg, et al. (2001) examined the differences in speech and prosody between normal subjects and 15 male subjects with high-functioning autism (HFA) and 15 male subjects with Asperger syndrome (AS). These were compared with 53 age-matched subjects with normal speech development (according to the Normal Speech Acquisition on the Speech Disorders Classification System). The researchers compared speech and prosody between the three groups. AS subjects are similar to HFA individuals except that people with AS do not have the communicative abnormalities and language delay that are characteristic of HFA.

They found few statistically significant differences between the HFA and AS groups, but the AS subjects showed a significantly higher tendency to use 'obsessive, repetitive topic expression.' For example, an AS subject might, if speaking about chocolate, utter a sentence similar to 'chocolate, chocolate, chocolate is sweet'.

In prosody, the HFA and AS groups showed a higher tendency, versus controls, for speech-sound distortions, phrasing, faulty use of stress, loudness (too high), and high pitch (too high). Speech-sound distortions occur when a subject mispronounces words. For example, if a subject were trying to say *dock* (/dak/), but distorted the word-final /k/ with voicing, then the subject might be misunderstood as saying *dog* (/dag/), which might only be discernable by context (if comprehensible at all).

Phrasing refers to HFA and AS subject sound/syllable/word repetitions, such as when a subject utters 'chocolate is IS sweet'. Unlike topic repetition, faulty phrasing deals with the meaningless repetition of a non-topic word. Shriberg, et al. (2001) note that phrasing errors did not correlate with higher speaking rate or high stress in the HFA and AS subjects.

Autistic and Asperger syndrome subjects also tend to apply stress incorrectly to a word. For example, stress is vital to disambiguating the part of speech for many English words, such as 'present'—the nominal form bears syllable-initial stress (*'pre •sent*), while the verbal form is stressed on the final syllable (*•pre 'sent*).

Shriberg, et al. do not attempt to explain why these phenomena occur more frequently in autistic/Asperger subjects than control subjects, but there are three possible explanations: either as (1) purely articulatory/motor errors, (2) purely perceptual/sensory errors, or (3) some combination of articulatory/perceptual mistakes. Options (1) and (3) cannot be discarded with present data (investigations into these questions might be very insightful), but in Chapter 2, I argue that evidence strongly supports (2).

1.1.1. Perceptual/sensory deficit defined. Before I begin describing the autistic language deficit, I need to define an important term: **quantification**. It will be shown that quantification processes lie at the heart of autistic dysfunction. Quantification deals with set-subset relationships. In traditional logic the basic **quantifiers** are ALL, SOME, and NOT. If I say that *ALL crows are black*. I am saying that the whole set of crows is black. If I say *SOME crows are black*. I am saying that only some *subset* of crows is black and some other *subset* is NOT black (see Figure 1.2).

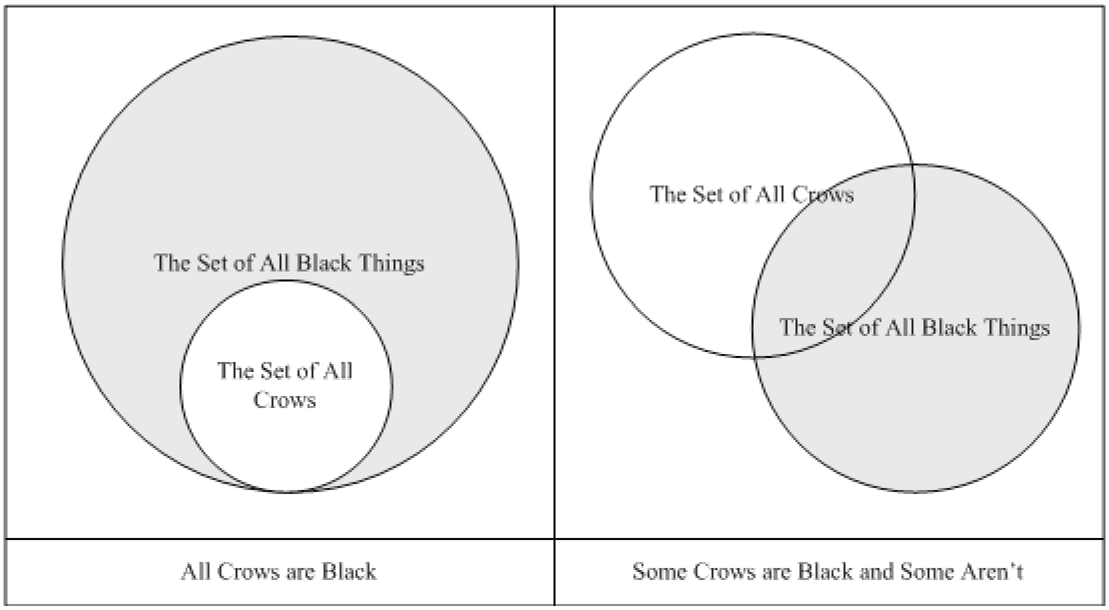


Figure 1.2. The set distinction between wide (left) and narrow (right) scope.

The key to understanding autism is to understand that set/subset distinctions made by normal language users are NOT made by autistic subjects. Returning to the pitch-change data, recall that autistic subjects did better at discriminating individual pitch changes, because they were not grouping similar contour patterns into perceptual sets; they did not "overgeneralize" the data, but rather they took each stimulus on its own terms. However, normal language function utterly depends on such generalizations: the ability to generalize and then subsequently differentiate (i.e. "quantify") general sets into subsets.

A similar explanation is available for the stress-error data: normally the nominal form bears syllable-initial stress (*'pre •sent*), while the verbal form is stressed on the final syllable (*•pre 'sent*). The nominal and verbal forms are related semantically, but the noun indicates **result** (a present was presented) while the verb represents a **process**. Result and process are subsets of a larger set, again unavailable for processing to the autistic subjects.

1.2. Morphological processing. Autistic children tend to have peculiar difficulty with properly using morphemes and auxiliaries (Sigman & Capps 1996:75) such as tense markers (Bartolucci 1972). For example, in data obtained from Dr. Tager-Fluberg (available through the CHILDES database), an autistic subject uttered the sentence 'Policeman open the door' without indicating the temporal context of the event.

(1.2a)	Policeman open the door.	[+NO TENSE]
(1.2b)	Policeman open-**ed** the door.	[+PAST TENSE]
(1.2c)	Policeman open-**s** the door.	[+PRESENT TENSE]

Example (1.2) demonstrates the actual autistic utterance, (1.2a), and two unrealized alternatives, (1.2b) and (1.2c). This type of untensed verb construction is typical of autistic language (Sigman & Capps 1996:75-76; Bosch 1970:121).

The relationship between tense and the matrix verb in these constructions is also an issue of quantification. Consider the sentence: *Mike will finish his$_i$ thesis*. This sentence implies a global event set: MIKE TO FINISH HIS THESIS, and his global set can be decomposed into separate subset events.

CAUSE:	Mike starts his thesis
PROCESS:	Mike writes his thesis
RESULT:	Mike finishes his thesis

Future tense provides information only about the truth-value of the *result* subevent. In this way, tense decomposes a verbal event into its subsets (subevents) and provides information about the truth value of one or more of these subevents; thus, tense is a type of quantification, as it provides more information about a subset (or subsets) of the event.

As a further example of morphological disorder, autistic people also tend to confuse case marking on pronouns. For example, they might mistakenly substitute *my* for *I* or *mine* (Churchill 1978:85; Bosch 1970:122).

Bartolucci, et al. (1980) compared acquisition of grammatical morphemes in autistic, mentally retarded, and normal children. Both autistic and mentally retarded subjects were slow in morphological acquisition compared with normal controls; and, furthermore, there were differences in acquisition between the autistic and mentally retarded groups—differences which led them to conclude that, whereas the mentally retarded group was experiencing a delay that corresponded to patterns in their global use of language, the autistic group was experiencing difficulties indicative of a delay particular to grammatical morphology. These conclusions were substantiated by Howlin (1984), who performed a study with a similar methodology. I will likewise argue that the specific difficulty with case marking is a function of a breakdown in quantification processes.

1.3. Semantic processing. Autistic children tend to perform similarly to normal children with respect to basic agent-patient syntactic relationships; however, they perform at much lower levels than normal children with respect to verbal negation (Shapiro & Kapit 1978). As noted earlier, propositional negation is a basic form of logical quantification. *NO crows are black* means the subset of black crows is empty. Autistic subjects shy away from constructions that negate a proposition, such as, 'Jenny will not go', where the proposition 'Jenny go' is negated.

(1.3) ¬/not(Jenny will go)

(1.3) illustrates a situation where the event (i.e. the verb 'go' and all of its arguments) are negated, but Shapiro & Kapit (1978) imply that non-verbal negation is unaffected. So, for instance, an autistic individual might utter a sentence like 'Jenny is impolite', as frequently as a normal individual. This type of construction, as opposed to (1.3), does not negate a whole verbal event/state; rather, it negates just a small part of the larger proposition, in this case, the adjective 'polite'.

(1.4) ¬/not(polite)

The difference between negating a whole proposition:

It is NOT the case that Jenny is polite

and negating an isolated piece of a proposition:

It is the case that Jenny is impolite

illustrates a process called **quantifier scope**. Whole-proposition negation has **wide scope**, while isolated-phrase negation has **narrow scope**. Quantifier scope will also prove quite important to my analysis.

Autistic subjects also struggle with deixis (Rees 1984). The deictic components of a sentence refer to 'terms whose contribution to propositional content depends on the context' (Chierchia & McConnell-Ginet 2000:333). Deictic expressions can refer to people (*I*, *you*), times (*now*, *then*, *soon*), places (*here*, *there*, *near*, *far*), etc. For example, the deictic expression 'now' in 'Jenny is now going to the store' refers to the specific time element for the event 'Jenny is going to the store'. 'Now' points to the event in the context of the present time.

According to model-theoretic semantics, deictic (Gk. 'display', 'show') expressions point to individuals, times, places, etc that are members of a set (see Figure 1.3). Accordingly, 'she' in 'She is happy' refers to the set of all people and specifically to a member of the subset 'she'. The important point, though, is that the member referred to in the set is dynamic. In other words, the pronoun 'her' in *Susan ate her dinner* has a different referent than in *Annie saw her picture*.

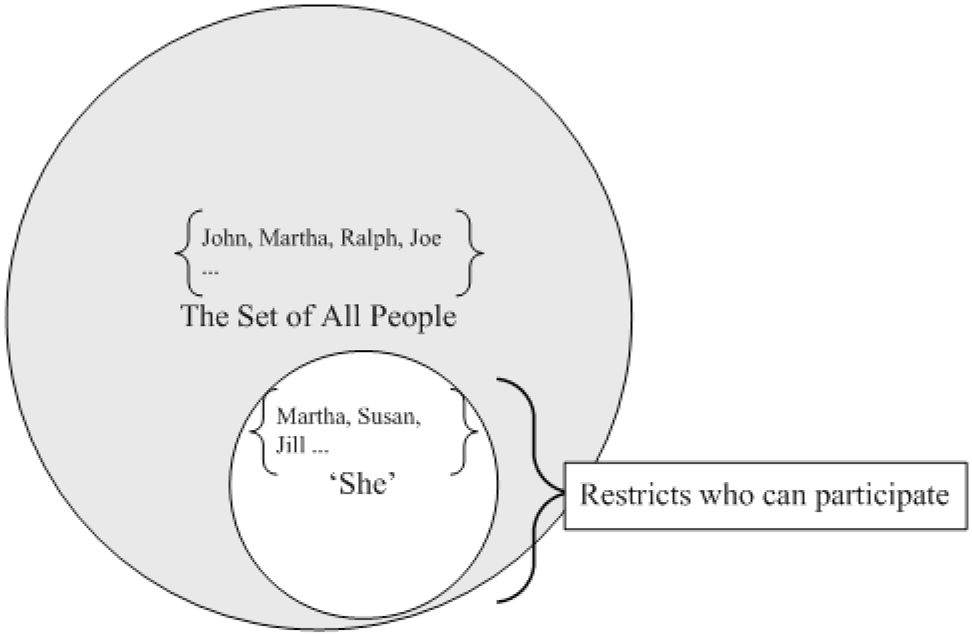


Figure 1.3. Set-subset relationship for deictic pronouns.

Churchill (1978:61-73) also found that autistic children have an unusually difficult time correctly leveraging prepositional syntactic relationships; in fact, they generally tend to shy away from the use of prepositions altogether.

The semantics of a sentence preposition is similar to negation in that the preposition's scope (quantificational strength) is also tied to whether it modifies a verb or a noun. Verb-modifying prepositions have **wide scope**, whereas noun-modifying prepositions have **narrow**, or "weak" scope. Example (1.6) shows contrasting sentences in which the preposition modifies a verb and a noun, respectively.

(1.6a) John left from the bus terminal.
(1.6b) John [$_{VP}$ left [$_{PP}$ from the bus terminal]]
(1.6c) John is a man from Nottingham.
(1.6d) John is [$_{DP}$ a man [$_{PP}$ from Nottingham]]

Sometimes resolving prepositional syntactic relations must occur with the aid of context, as in the sentence 'I saw the man with a telescope'. Alternate parses of this sentence are reflected in Figures 1.4 and 1.5.

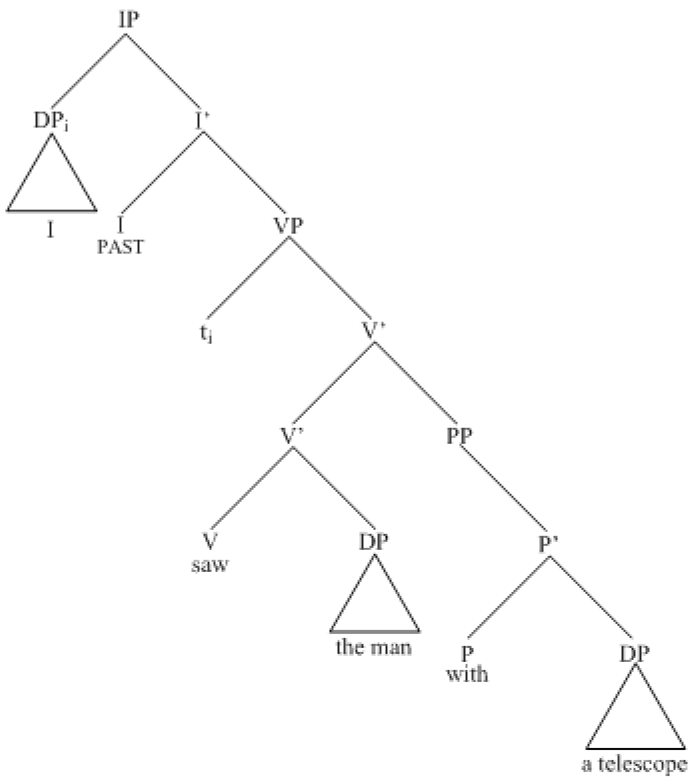


Figure 1.4. Parse of 'I saw the man with a telescope' where 'with' has wide scope over the verb.

Figure 1.4 reflects the X-bar parse in which 'with' modifies the verb 'saw' (instrumental reading of 'with'). This reading literally means that the telescope is the instrument that I use to see the man. Another way of describing this situation is to say that 'with' quantifies over the matrix verb 'saw'. In Chapter 2, we will see that syntactic scope relationships have important consequences for semantic interpretations of argument structure, effects which are central to autistic language.

In contrast, Figure 1.5 shows a potential parse of 'I saw the man with a telescope' where 'with' modifies the determiner phrase (DP) 'the man'. This literally means that 'the man' is either in close proximity to a telescope or owns a telescope.

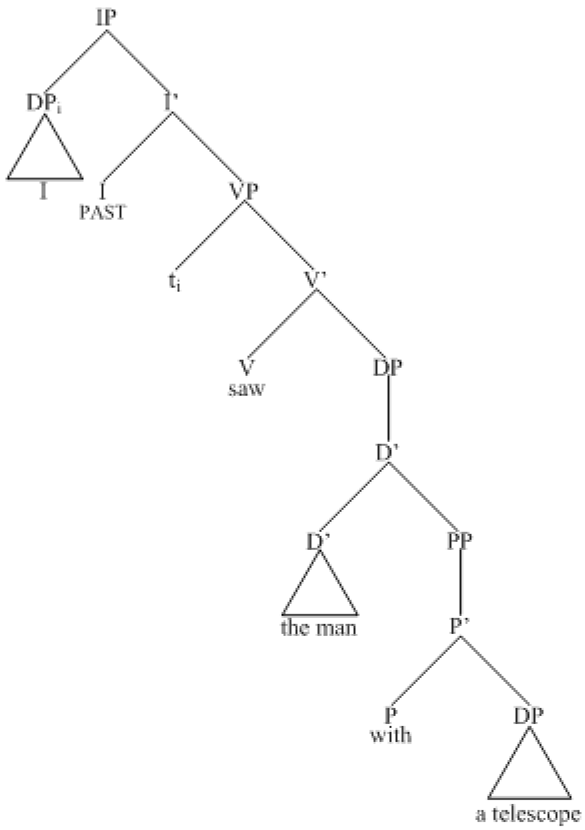


Figure 1.5. Parse of 'I saw the man with a telescope' where 'with' has narrow scope.

With the help of contextual information a hearer may prefer one reading (either the parse in Figure 1.4 or Figure 1.5) over another. For example, if my friend says 'Just a second ago, I saw the man with a telescope' and my friend is holding a telescope, then I will probably prefer the instrumental reading of 'with'. However, if my friend does not have a telescope and there is not a telescope in the vicinity that my friend could use, then I will probably assume that 'the man' was carrying a telescope, or owns a telescope.

Prepositional phrases (PPs) modifying events restrict the event to a certain location, manner, etc, and therefore involve quantification. Consider the sentence: 'Mary went to the store'. The PP 'to the store' picks out a particular instance when the event 'Mary went' is true (i.e. a particular member of the set of possible events where 'Mary went'). The PP thus restricts the members of the predicate set participating in the proposition by quantifying over the verbal event (see Figure 1.6).

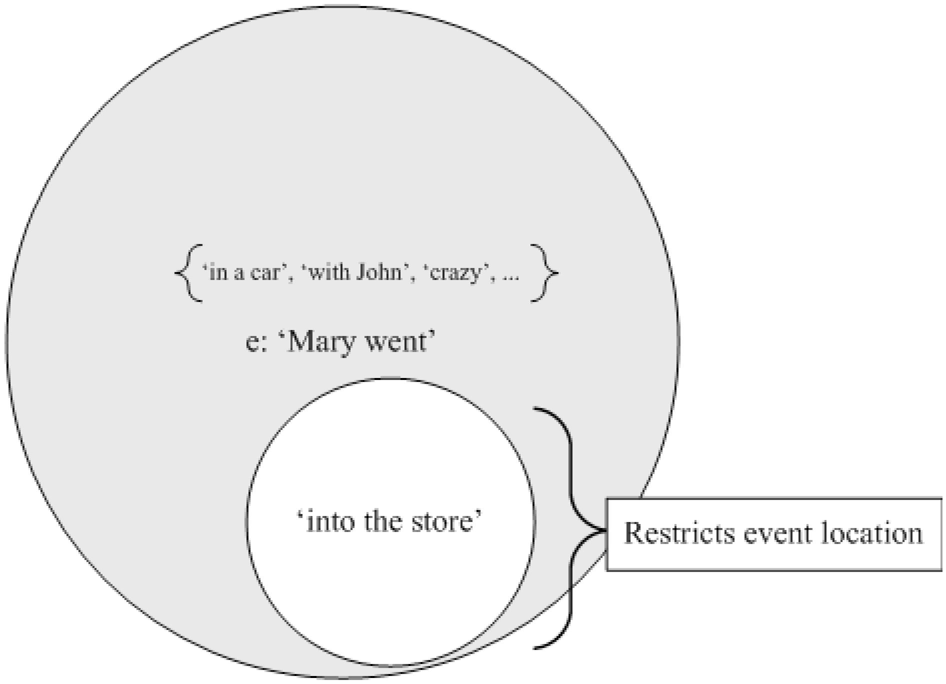


Figure 1.6. Diagram reflecting prepositional quantification.

The fact that autistic subjects have a difficult time sorting out prepositional syntactic relations thus reflects a decreased efficiency in comprehending prepositional quantification or in using contextual clues to resolve attachment ambiguities, or both.

Tager-Flusberg, et al. (1990) compare the language of 6 autistic children with 6 age-matched Down's children by comparing mean length of utterance (MLU) and IPSyn (index of productive syntax) between the two groups. They found that autistic subjects show a precipitous decline in MLU after approximately ten months of normal language development, as indicated by Stuart (one of the autistic subjects in the study). During the first six months of the study, Stuart's MLU increased from 1.17 to 2.15, but between the ninth and tenth months of the study his MLU dropped sharply to 1.47. Such a decline is not characteristic of Down's syndrome children.

The paper also observes that over time as the average MLU for autistic subjects increases they tend to use a more restricted set of syntactic structures. So, even as their language developed, the autistic subjects were likely to continue to use simple transitive sentences such as ‘policeman open the door’, as opposed to its passive counterpart ‘the door was opened by the policeman’, repeatedly using the active constructions. Put differently, ‘autistic children tend to rigidly depend on a particular sentence structure even though they have the knowledge to employ greater variety in their speech’ (Tager-Flusberg, et al. 1990). Down’s syndrome subjects do not demonstrate such inflexibility.

Tager-Flusberg, et al. found two other significant grammatical differences between autistic and Down’s children: (1) during early language development, autistic children use specific nouns more frequently than closed class words (like auxiliary verbs, conjunctions, determiners, prepositions, and pronouns)—the opposite is true for Down’s children. For example, an autistic subject was more likely to utter a sentence like ‘dog eats cake’ than a sentence with closed class words such as ‘the dog should eat cake and ice cream.

(2) Autistic children are less likely to use pronominal forms than Down’s children. So an autistic child, referring to another person is more likely to use that person’s name (‘the dog bit *John*’) or a description of the person (‘the dog bit *the mailman*’) rather than substitution with a pronominal (deictic) term (‘the dog bit *him*’).

An important observation not made by Tager-Flusberg, et al. is that closed class words often quantify over sets of events/states (e.g. auxiliaries), individuals (e.g. pronominals), sets (e.g. determiners), locations (e.g. prepositions), or truth-values (e.g. negation, modals).

Nuyts and de Roeck (1997) studied the ability of high-functioning autistic individuals to generate meta-representations based on their linguistic use of epistemic modality. They measured modal adverbs, predicate adjectives, mental state predicates, and auxiliaries in autistic versus control participants. Modal adverbs, such as ‘probably’ and ‘possibly’, often indicate the likelihood of a verbal event/state, as in (1.7).

(1.7) Rachel will *probably* go to the store.

In (1.7), ‘probably’ provides additional information about the event ‘Rachel go to the store’. As just mentioned, this modal adverb provides information about the probability of the event ‘Rachel go to the store’ occurring.

Predicate adjectives (e.g. ‘possible’ and ‘probable’) are conceptually similar to modal adverbs in that they also provide additional information about a state/event, as demonstrated in (1.8).

(1.8) It is *probable* that Rachel will go to the store.

The predicate adjective in (1.8) works in essentially the same way as the modal adverb in (1.7)—indicating the probable truth-value of the event ‘Rachel go to the store’. Mental state predicates are verbs such as ‘believe’ and ‘think’, that hold scope over a verbal event/state, as indicated in (1.9).

(1.9a) I *think* that Rachel will go to the store.
(1.9b) I *think* $[_{CP}$ that $[_{IP}$ Rachel will go to the store]]

Notice that mental predicate verbs often subcategorize for a complementizer phrase (CP), as in (1.9) where the CP (headed by ‘that’) c-commands the proposition ‘Rachel will go to the store’.

Some auxiliaries also indicate epistemic modality. For example, ‘must’ governs a verbal event/state and indicates the necessity of an event/state occurring, as demonstrated in (1.10).

(1.10) Rachel *must* go to the store.

This example demonstrates that 'must' provides information about the unrealized truth-value of the proposition 'Rachel go to the store'. In other words, 'must' indicates that the event has not yet occurred, but that it will occur sometime in the future. In this way modals restrict the verbal event by the probability that the event will occur (as in epistemic modality) or by the amount of obligation that connects the referent ('Rachel') to the event (as in deontic modality). For example, 'must' in (1.10) indicates Rachel's obligation (deontic modality) to perform the event 'go to the store', as reflected in Figure 1.7.

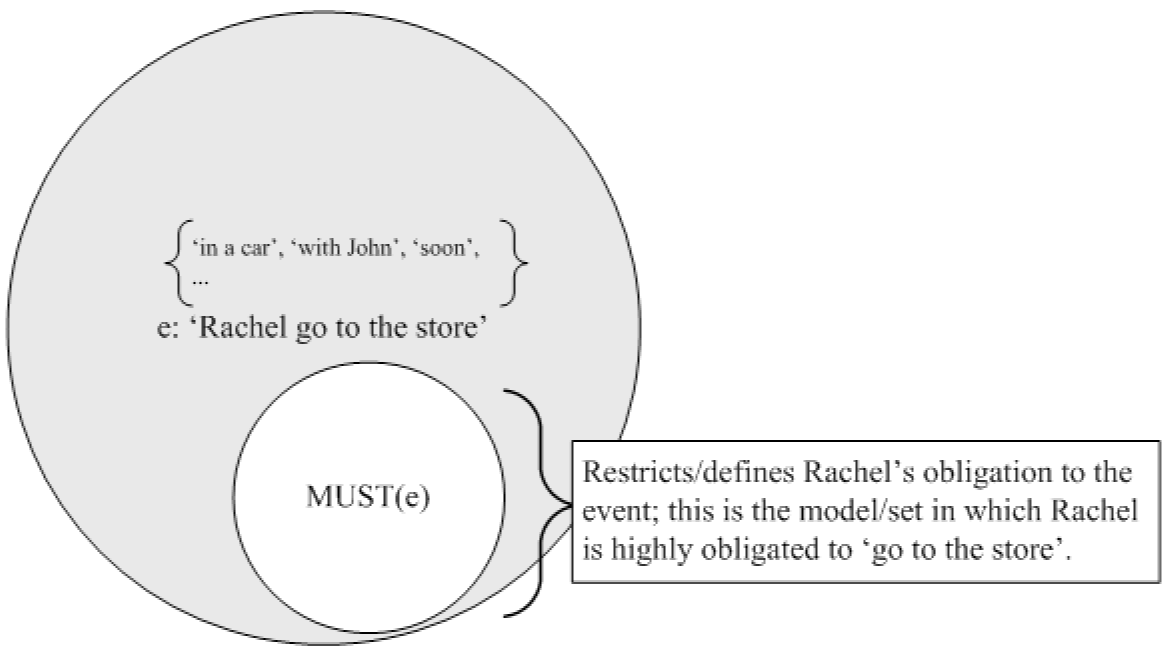


Figure 1.7. Modality as an instance of quantification.

Nuyts and de Roeck (1997) found that only one of the four autistic subjects tested showed decreased ability to represent epistemic modality compared to controls, and subsequently concluded that epistemic modality is a poor theory to describe autistic cognitive dysfunctions.

1.4. Autistic syntax. To this point, I have described quantification mostly in terms of semantics. Figures 1.4 and 1.5 indicate how quantification relationships are also represented syntactically by c-command. A syntactic $node_1$ c-commands another $node_2$, if $node_1$ is the sister of a node which is parent to $node_2$. Consider, for example, the sentence: 'John$_i$ likes himself$_i$'.

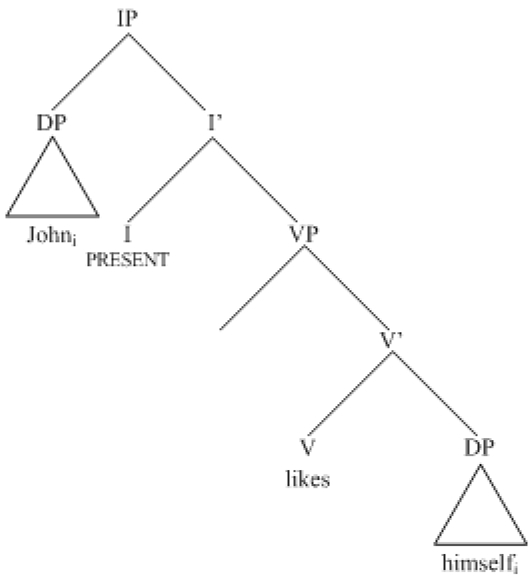


Figure 1.8. Syntactic representation of 'John$_i$ likes himself$_i$'.

In Figure 1.8, 'John' c-commands 'likes' and 'himself' because its sister node (I') is parent to 'likes' (V^0) and 'himself' (DP); likewise, present tense c-commands 'likes' and 'himself'. Syntactic c-command is a way of representing semantic quantification; thus, a category in a higher c-command relation to a verb quantifies more forcefully over the verb and its arguments.

1.5. Autistic pragmatics/behavior. Pragmatic/behavioral dysfunction is easily the most documented area of autistic language. Recent research has paid particular attention to the autistic 'theory of mind' deficit. Uta Frith's 1993 article in *Scientific American* brought 'theory of mind' to the public attention, and subsequent work such as *Mindblindness* (1995), by Simon Baron-Cohen, has further fueled interest in the idea.

By definition, 'theory of mind' is 'the ability to attribute mental states to self and others, and to predict and understand other people's behavior on the basis of their mental states' (Fine, et al. 2001). Stated differently, 'theory of mind' is the ability to *reflect* on one's own and/or another's beliefs and intentions. This process requires the drawing of presuppositions. The PBS series *Evolution*, produced by WGBH Boston, portrays a classic experiment used to test for 'theory of mind' abilities in children. A child subject is presented with two dolls, a marble, a basket, and a box. Doll$_1$ places the marble in the basket and covers it with a handkerchief; doll$_1$ then leaves. Next, doll$_2$ enters, removes the marble from the basket and places it in the box, and doll$_2$ exits. The experimenter then asks the child subject where doll$_1$ will look for the marble when she returns. Autistic subjects and children who are younger than (approximately) four years claim, falsely, that doll$_1$ will look for the marble in the box, as they are unable to separate their perception of the situation from the perception of doll$_1$. A person with a 'theory of mind' deficit is unable to comprehend that her perception of a situation is relative to her unique perspective.

A 'theory of mind' deficit presupposes a mind-reading deficit. According to Baron-Cohen, the ability to mind-read requires four stages of development—volition, perception, shared attention, and representing epistemic states; and the final stage—representing epistemic states (of one's own and others') requires theory of mind (1995:31). Leslie (1994) suggests that these epistemic representations (called 'meta-representations' or 'M-representations') have the form '[Agent-Attitude-Proposition]'. Accordingly, the sentence 'Joe believes that Julie is telling the truth', has the form '**[Joe(AGENT)-believes(ATTITUDE)-Julie is telling the truth(PROPOSITION)]**'. According to my interpretation, this implies that in order to 'believe' something about someone else, one must abstract/quantify a belief-state—a presupposition—over another's actions. For example, if I told my friend that 'K-Mart is having a sale on Preparation H', I would do so on the supposition that my friend needs Preparation H (**I-believe-my friend needs Preparation H**). This process of presupposition suggests a process of abstraction to interpret another's thought.

‘Theory of mind’ requires quantification, as my belief state(s) must quantify over another’s mental state. Reconsider the doll example:

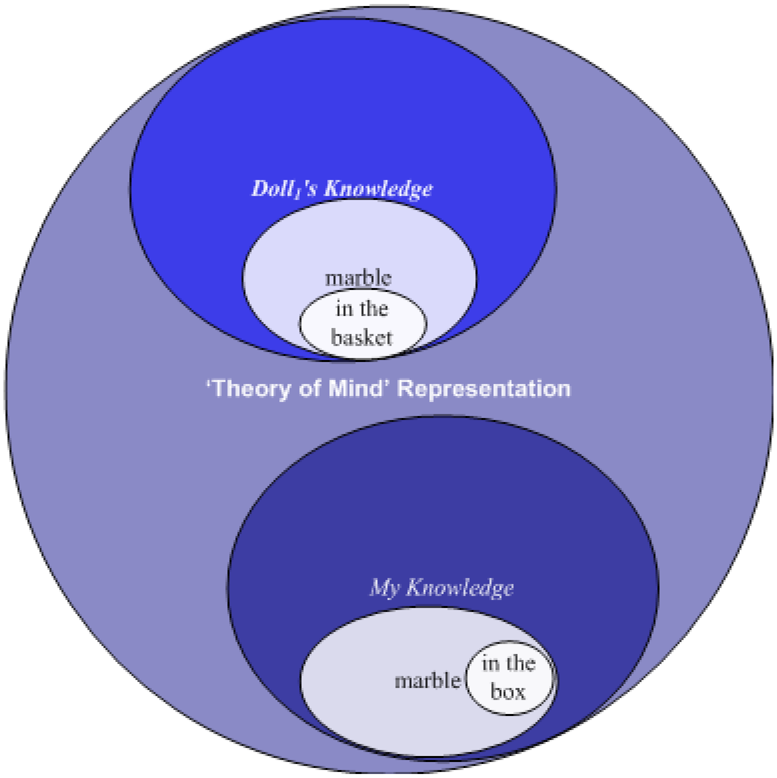


Figure 1.9. A set-subset diagram of ‘theory of mind’.

‘Theory of mind’ (ToM) requires me to represent two knowledge states: (1) my own (i.e. to understand what I know about the situation) and (2) doll$_1$’s knowledge of the situation (i.e. doll$_1$ put the marble in the basket and was not present when the marble was moved). It also implies, at least in this case, propositional negation:

- if doll’s knowledge = marble in basket,
- and if my knowledge = marble in box,
- then doll’s knowledge ≠ my knowledge

The fact that ToM requires negation is important, as it unifies ToM with the autistic dysfunction in linguistic negation. Leslie’s description is an important step forward in understanding the autistic deficit. Later in this thesis I will show that combining Leslie's formal representation of the 'theory of mind mechanism' with model-theoretic semantics lends important insights into the cognitive etiology of the autistic deficit—linguistically and behaviorally.

In addition to 'theory of mind', there are currently two other mainstream theories aimed at describing autistic behavior—executive dysfunction and weak central coherence.

According to Hughes, et al. (1994), executive function refers to 'the mental operations which enable an individual to disengage from the immediate context in order to guide behavior by reference to mental models or future goals.' Planning is an excellent example of an executive function. So, if I'm playing golf, for instance, on a par 5 hole I need to plan out steps to getting the ball from the tee into the hole. If I fail to plan, then the result could be disastrous, as my ball might end up in a sand trap or water hazard (which usually occurs anyway). Executive dysfunction attempts to describe an autistic individual's inability to plan flexibly, suppress incorrect responses, and retain relevant information in working memory. Poor performance on the 'Tower of Hanoi' puzzle is a good reflection of executive dysfunction, and indeed, autistic individuals perform poorly on this task (Hughes, et al. 1999).

Just like ToM, normal executive function requires quantification. Consider the golf example: planning is a goal-directed behavior (e.g. goal = ball in hole) that necessitates the positing of subgoals to successfully accomplish the task at hand. In other words, the overall goal of getting the ball into the hole can be quantified or subdivided into distinct subsets: (1) draw the ball around the trees on the left to place the ball for an easy approach shot; (2) land the ball just short of the green so it can trickle up and stop below the hole; and (3) it looks like this putt will move from right to left, so I need to take that into account when calculating the speed and direction of the putt; and so forth.

Executive-type dysfunction is not unique to autism, but is characteristic of individuals with schizophrenia, obsessive-compulsive disorder, ADHD, and other disorders. Research has implicated damage to/abnormal development of prefrontal cortical areas that lead to executive dysfunction and perseverative behaviors (Goldberg, et al. 1987; Guzelier, et al. 1988).

The 'weak central coherence' approach to autism, on the other hand, states that autistic individuals are unable to represent high-level meaning—indirect references that require the hearer to 'get the gist' of what the speaker is trying to say/infer (Frith 1989). For example, if someone said 'there sure is a breeze in this room', an autistic person might not understand that the speaker wants someone to close the door.

1.6. Summary of previous research on autistic language. Figure 1.10 summarizes the language and behavioral abnormalities in autism.

Phonology	Echolalia Monotonic Prosody
Morphology	Pronominal Case Marking Tense Marking
Syntax	Negation Tense Modals Prepositional Syntactic Relations
Discourse/ Pragmatics	'Theory of Mind' Deficit Executive Dysfunction Weak Central Coherence

Figure 1.10. A summary of previous work on autistic language dysfunction.

It is important to note that these findings are preliminary in that many of the observations made in the literature are almost anecdotal, which suggests that more quantitative studies need to be done to compile a justified list of dysfunctions. Even so, I will make the best use I can of the available data, and, indeed, there is a striking generalization that emerges from Figure 1.10, a generalization that I address throughout the remainder of this thesis.

1.7. Unanswered questions. Past research on autistic language has been highly descriptive in nature and, for some reason, researchers in this area have failed to make fundamental observations about the data that would begin to explain what these language problems share in common with autistic behavioral abnormalities. This thesis, however, will attempt a correlation and a demonstration that these linguistic and behavioral data are consequences of a single deficit in autistic cognition—that of quantification.

My approach to the autistic language problem presumes that language, like other cognitive functions, is goal-directed to convey meaning (semantics); in other words, it assumes that phonological, morphological, and syntactic representations generate semantic interpretations. *How* the levels interface is a subject of debate in the linguistic community, and is happily irrelevant to this treatment of autistic language. For the sake of consistency, I use X-bar syntactic representations and model-theoretic semantic representations, as they are the 'party line' theories in linguistics today, but other theories (such as HPSG, CG, LFG, etc) could also be used to demonstrate the quantification hypothesis.

Here is an example that illustrates how semantic representations are interpreted from syntactic structure.

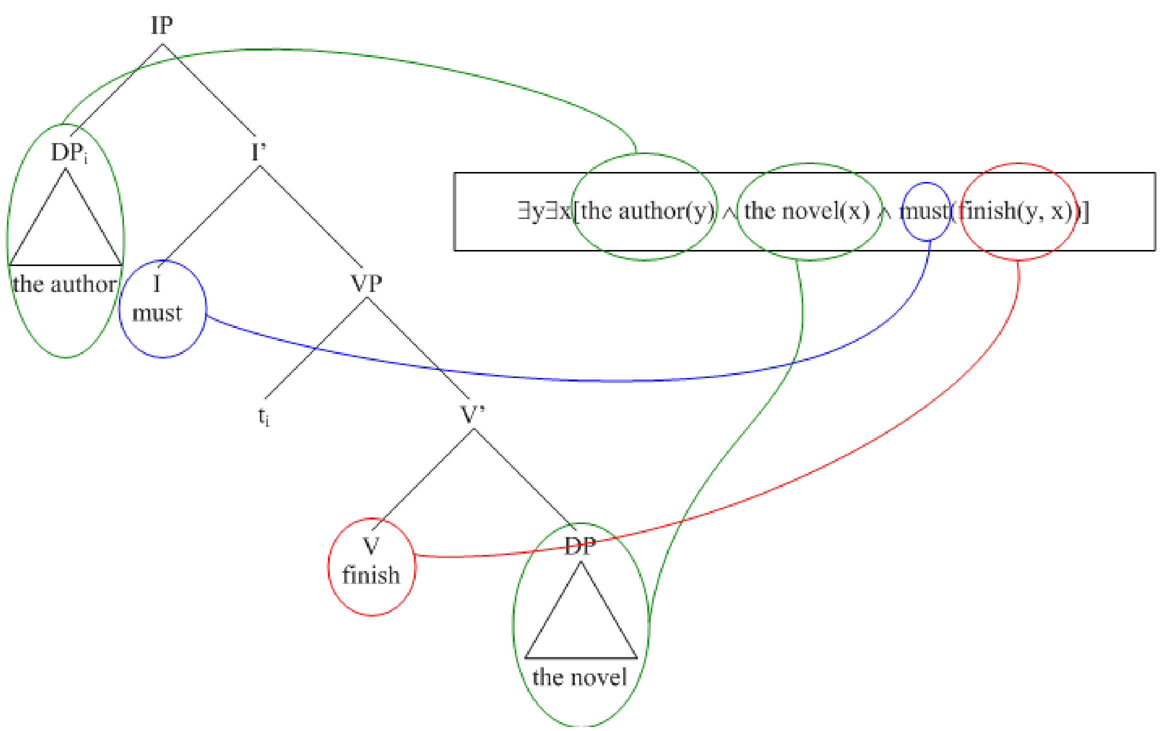


Figure 2.1. Mapping between syntax and semantics.

Figure 2.1 reflects the mapping from syntactic to semantic structure. The semantic structure at the right is a predicate calculus (PC) representation, which gives a general representation of the semantics for the string 'the author must finish the novel'. The PC representation shows that the modal 'must' and the verb 'finish' map to hierarchical predicate positions in the PC, while the determiner phrases 'the author' and 'the novel' map to arguments of those predicates (external and internal, respectively).

2.1. Aristotelian logic. The Greek philosopher Aristotle (384-322 BC) is, perhaps, the most renowned thinker in history, and his writings on logic were considered the definitive work until the early nineteenth century. In his *Organon* (Gk. 'instrument'), Aristotle outlines the rules of logic. He also draws a distinction between two types of logic: dialectic and analytic. Dialectic, Aristotle argues, examines beliefs for their logical validity. Analytic, on the other hand, infers using experience and observation (Bodéüs 1999:60-62).[2] Put differently, dialectic is induction, while analytic is deduction. Deduction allows us to draw specific conclusions from generalizations, whereas induction extracts possible (not conclusive) general inferences from particular instances.

In the *Organon*, Aristotle also proposes a system of categorical logic, which regards subject-predicate assertions as the primary expressions of truth. For example, the meaning of 'Rose threw the ball' is inseparably tied to the relationship between the predicate 'threw' and the subjects 'Rose' and 'ball'. In this system, features or properties are shown to inhere in individual substances, so the predicate 'threw' inherently subcategorizes for an external argument 'Rose' and an internal argument 'ball'. In every discipline of human knowledge, then, we seek to establish that things of some sort have features of a certain kind. This work laid the foundations of predicate logic—notions which were later expanded by Leibniz, Peirce, Frege, Russell, and other important language philosophers.

2.2. The predicate calculus. Aristotle's syllogistic logic was problematic, however, as it was represented using regular language, and thus was subject to the ambiguities associated with natural language. Additionally, it was unable to represent complex predicates. Gottfried W. Leibniz was the first to suggest a formalism for language similar to the mathematical formalism. Leibniz's predicate calculus made two major innovations over syllogistic logic. First, a notation of connectives/conjunctions was developed (and, or, if, etc.), which made it possible to relate and evaluate the truth-value of two or more interacting syllogisms as a single proposition. Secondly, the predicate calculus introduced quantifier-variable notation. Thus the sentence '*x* is mortal' predicates a quality (mortal) of *x* in the same way that 'Socrates is mortal' predicates a quality of Socrates.

The predicate calculus representation consists, basically, of arguments (subjects, and predicates) and relationships between those arguments. With this new formalism the sentence, 'The children threw the ball', is represented as two subjects ('children' and 'ball') and one predicate ('threw'), as reflected in Figure 2.2b (the syntactic parse is reflected in Figure 2.2a). Part (c) of Figure 2.2 reflects a discourse representation structure (DRS), which might be easier for some readers to understand.

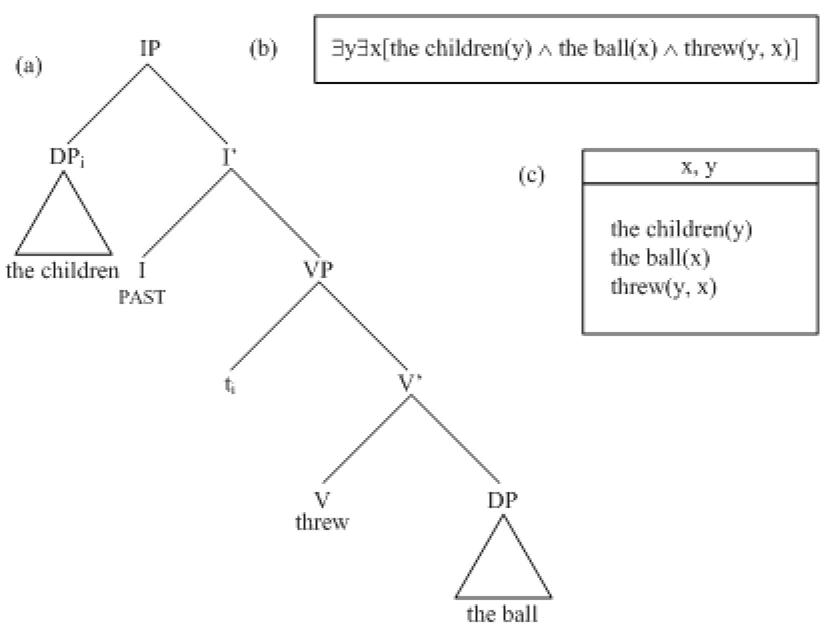


Figure 2.2. X-bar syntactic and first-order PC representations of 'the children threw the ball.'

Figure 2.2a shows a trace (t_i) in spec-VP which is coindexed with spec-IP (DP_i). This shows the concept of subject raising: 'the children' are part of the VP (the first-order predicate) but, as an external argument of the verb, it *raises* to the IP (the higher-order predicate).

In this example, the predicate 'threw' defines the relationship between both subjects, and because it's a transitive verb, it will take two arguments. This assignment of arguments by verbs to referring expressions is the core of predicate calculus. Predicate logic subdivides into two basic types, first-order and higher-order predicate calculus. Basically, first-order predicate calculus can represent simple predicate-argument relationships (restricted to verbal arguments), whereas higher-order predicate calculus was designed to articulate generalizations about individuals and their properties. In other words, higher-order logic denotes quantification (scope) over verbs and verbal arguments.

Higher-order predication works by applying first-order predicates as subjects of higher-order predicates, a concept reflected in the sentence 'A runner must run', which contains one subject ('runner') and two predicates ('must' and 'run'). Figure 2.3b shows the predicate calculus representation for this sentence.

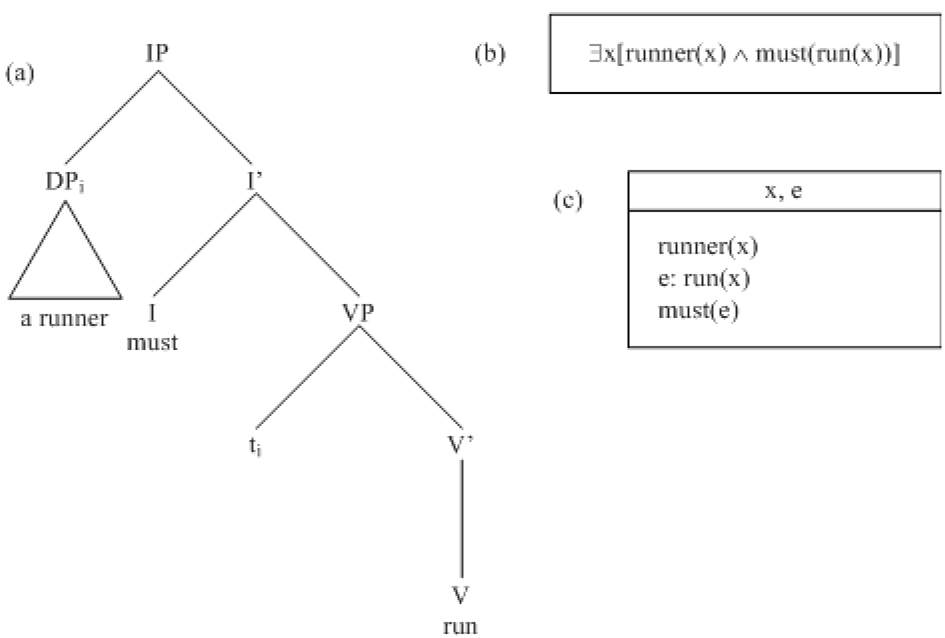


Figure 2.3. X-bar syntactic and second-order PC representations of 'a runner must run.'

Addition of the modal ‘must’ to the sentence forces the representation from first-order to higher-order predicate logic, as it makes the event ‘run’ (e) a subject of the modal ‘must’. So, in this example there are two subjects—x and e—and a single predicate ‘must’. In this way, higher-order predicate calculus ‘substitutes, for a complicated tangle of predicates attached to one subject, a single conception’ (Peirce 1931-1958:2.643).

Several linguistic phenomena can quantify over predicates, including tense and aspect markers (see Example 1.2), modals (see Figure 2.3), prepositions (see Figures 1.4 and 1.5), and negation (see Example 1.7). Interestingly, these linguistic categories that quantify correspond to the language dysfunctions characteristic of autism that I documented in Chapter 1.

Citing this strong correspondence between higher-order predication and the language difficulties in autism, I propose a hypothesis (2.1) and further investigation of this phenomenon.

(2.1) The Quantification Hypothesis: The autistic language condition is characterized by a specific linguistic dysfunction/difficulty: quantification.

If the Quantification Hypothesis (QH) is true, then one would expect to find that, in contrast with subjects with a global language deficit (such as in Down’s syndrome and other types of mental retardation), autistic subjects perform with comparable deficits on higher-order predication but better than their mentally retarded counterparts on first-order predication. Studies in Chapter 3 will test QH accordingly.

Before I begin my reanalysis of past research, I should say a few words about the qualities of quantification. By definition, ‘quantificational expressions introduce the power to express generalizations into language, that is, the power to move beyond talk about properties of particular individuals to saying what quantity of the individuals in a given domain have a given property’ (Chierchia & McConnell-Ginet 2000: 113-114). In language, the matrix verb in a sentence quantifies over its arguments because it provides information about their behavior. For example, in the sentence 'John ate pizza,' the matrix verb 'ate' is a predicate that quantifies over its external argument 'John' and its internal argument 'pizza'. One way to represent the predicate calculus for this sentence is shown in (2.2).

(2.2) **ate**(John, pizza)

The parentheses denote the scope of the predicate's quantification, so in the case of (2.2) the extent of predication by 'ate' is restricted to two arguments—'John' and 'pizza'.

According to the informal definition of quantification I introduced in Chapter 1 'ate' gives more information concerning its arguments ('John' and 'pizza'). This is demonstrated in the figure below.

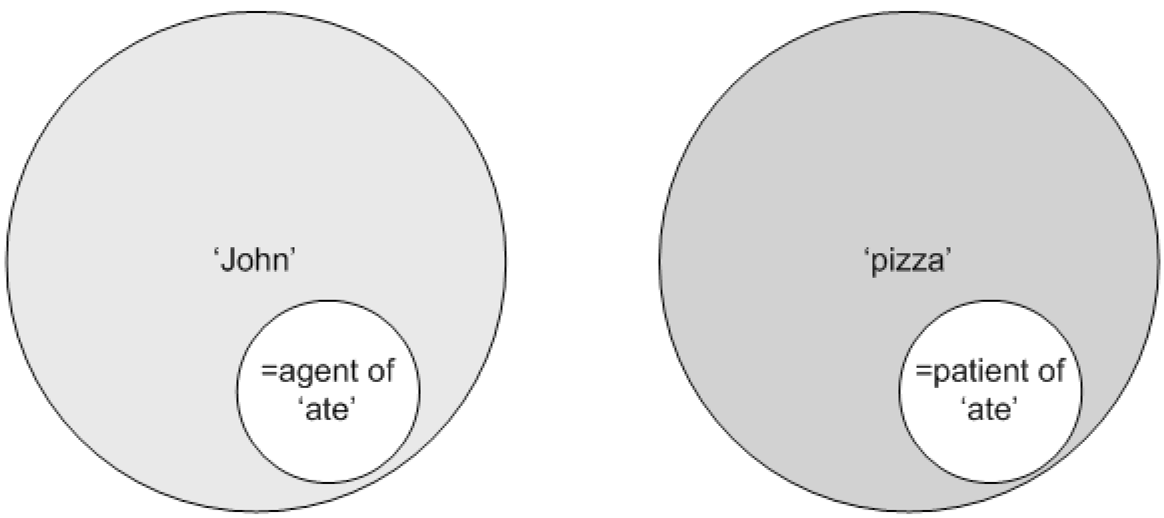


Figure 2.4. Set-theoretic drawing of 'John ate pizza'.

Thus, according to the relationship reflected in Figure 2.4, 'ate' provide information about the actions of 'John' and the fate of the 'pizza'.

2.3. Autistic phonology and quantification. In Chapter 1, I noted that autistic individuals tend to use prosody that is contextually inappropriate. Autistic prosody is also characteristically flat and choppy, which often makes the speech of autistic subjects difficult to understand (Lamers & Hall 2003; Shriberg, et al. 2001; Ramberg, et al. 1996). Most studies on autistic prosody simply describe it according to the autistic subject's degree of variance from the norm, but this does not explain *why* these prosodic irregularities exist.

As mentioned in Chapter 1, prosody in English is often used to denote the focus/topic of the sentence, as in 'BOB bought beer', where the rise of prosody on 'Bob' denotes the focus of the sentence. According to syntactic accounts, focus marking involves a tense phrase (TP) and longer syntactic movement by the focus subject (versus a non-focus subject), as illustrated in Figure 2.5.

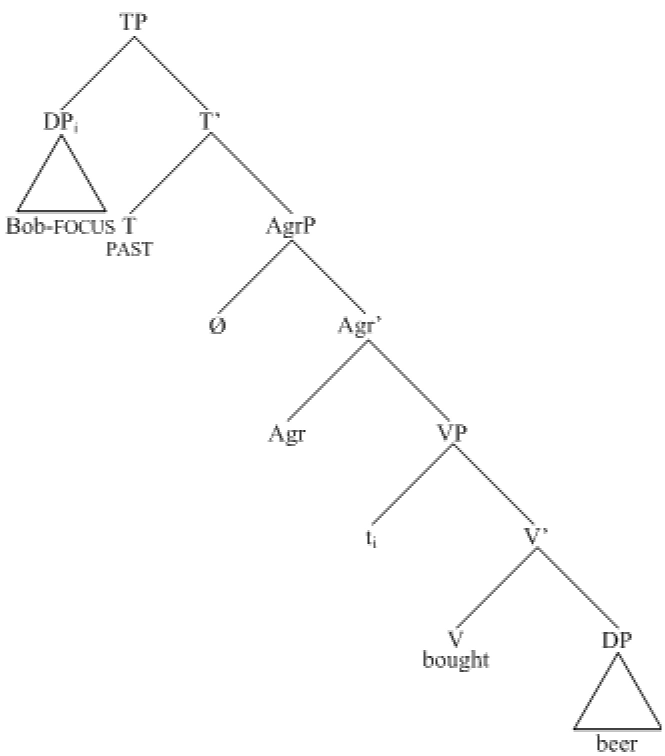


Figure 2.5. Syntactic representation of a focused subject.

Notice that in Figure 2.5, the focus subject 'Bob' must move over an extra phrasal boundary (AgrP) in order to properly represent focus. This introduces the notion that syntactic movement may metaphorically describe some of the language problems inherent in autism. Extra movement is necessary in focus constructions, as the focused item must abstract greater scope over the event, a process which allows the hearer to understand that the event is not the central item (which it generally is), but that the subject (or object, etc) is now the focal entity in the sentence. The fact that autistic subjects have well-documented difficulty representing focus may, therefore, point to a decreased ability to quantify over verbal events/states.

2.4. Autistic morphology and quantification. In Chapter 1, I listed the findings of previous research on autistic morphological dysfunction. That list is reproduced below.

- Pronominal Case Marking
- Tense Marking

So what do these morphological phenomena have in common? This is the vital question which the literature leaves unanswered, and which this thesis is intended to address. I will attend to each of these points separately.

2.4.1. Tense. Tense is a difficult linguistic phenomenon to categorize, as it can be approached either morphologically or syntactically: morphologically, since, in many languages, tense is an inflectional or derivational form of the verb (ex. '-s' and '-ed' in English) or a separate lexical form (ex. 'will' in English); and syntactically, because tense (I^0 in X-bar syntax) governs the complement verb phrase.

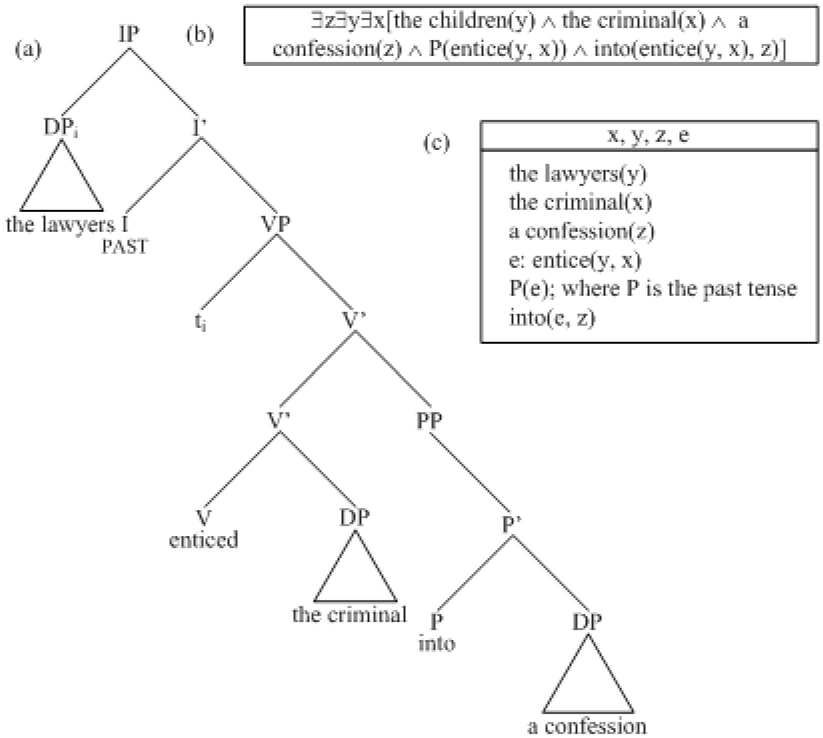


Figure 2.6. Representations of 'the lawyers enticed the criminal into a confession'.

Regardless of how one categorizes tense, its function, independent of the language involved, is to 'locate events in time with respect to a fixed temporal reference point and then specify the relation of the event to that temporal center by some direction and some degree of remoteness' (Frawley 1992:340). For example, the future tense marker 'will' in 'I will go to the store' marks the time frame of the event 'I go to the store'. In this way, tense c-commands an entire clause (a verb phrase and all of its arguments) and thus, tense must be represented using higher-order predicate logic. Figure 2.7b demonstrates the predicate calculus representation of 'A linguist interpreted the sentence.'

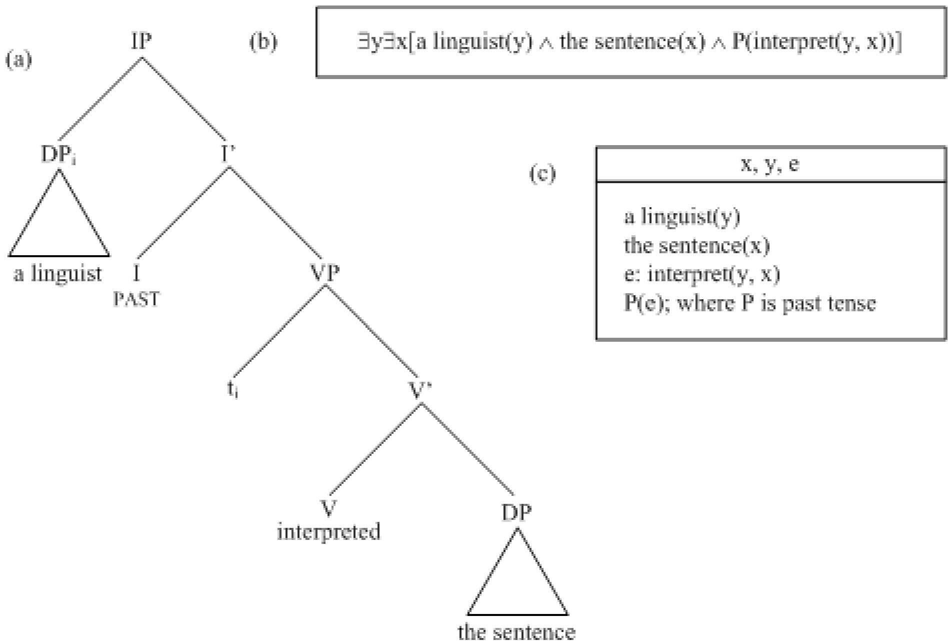


Figure 2.7. The X-bar and PC representations for 'a linguist interpreted the sentence.'

Figure 2.7b shows that the past tense ('P') quantifies over the entire event of opening the can. The fact that autistic subjects have difficulty with tense suggests that they might also have trouble with other semantic operators that quantify over verbs, and I will show throughout this chapter that this is the case.

Dr. Helen Tager-Flusberg gave me data to analyze from a corpus of sentences produced by autistic and Down's subjects available from the CHILDES database[3]. These data revealed, in conformity with previous research, that tense is often dropped or misused by autistic subjects. An example comes from an autistic subject's discourse with his mother, where the subject is trying to say that 'The policeman will open the door' (an assumption I make from the context of the utterance), but the actual sentence he utters is 'Policeman open the door.' At first glance, it might seem that a single word difference is not terribly significant, but the complexity of a sentence is not necessarily proportional to its length (an assumption of mean length of utterance (MLU) studies).

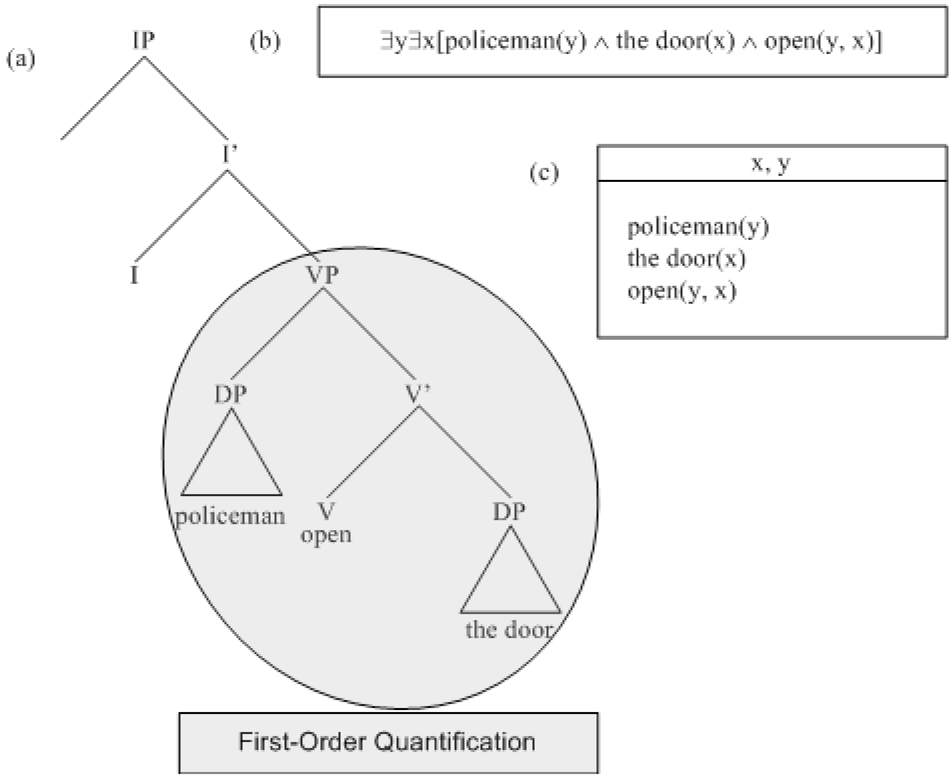


Figure 2.8. The X-bar and PC representations for 'policeman open the door.'

The sentence in Figure 2.6 does not have a tense marker (which would normally be positioned in I^0), so subject raising by 'policeman' to spec IP is unnecessary; thus all of the first-order predicates are contained under the VP shell and as such are participants in first-order quantification.

The predicate calculus representations of these sentences reveals that the difference between the sentences is the degree of quantification—the sentence without tense requires only first-order predication, while adding the tense marker necessitates second-order predication, as revealed in Figure 2.9.

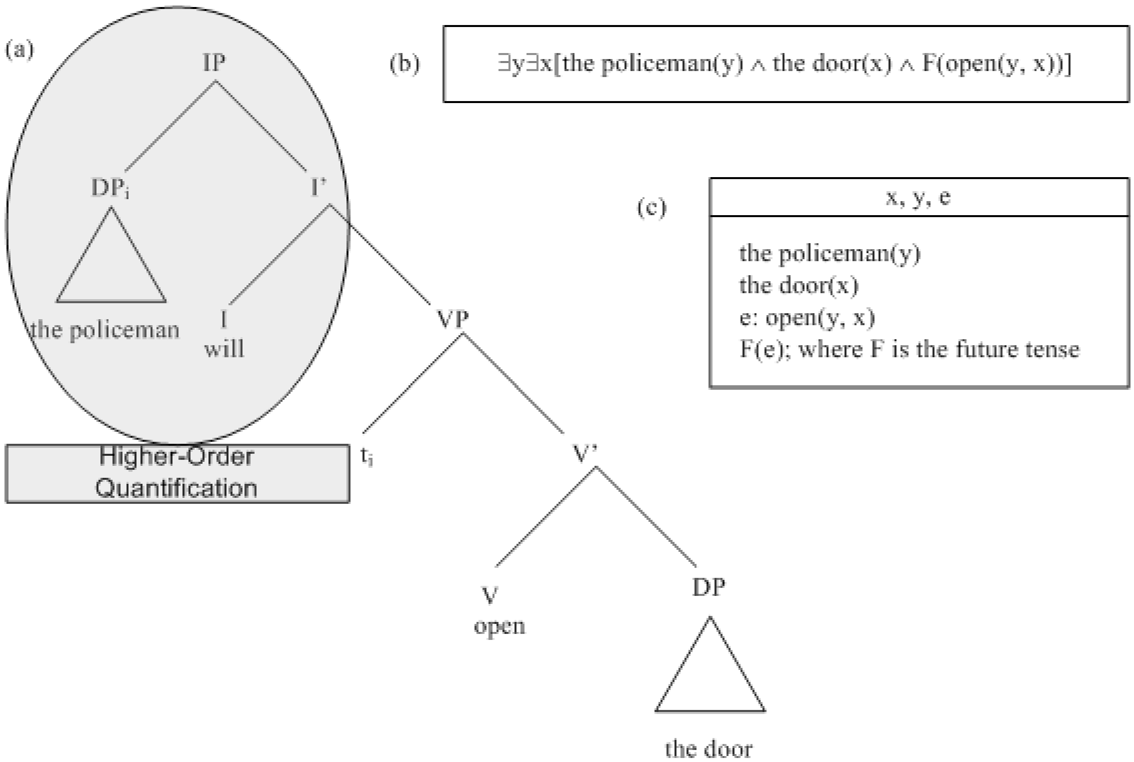


Figure 2.9. The X-bar and PC representations for 'the policeman will open the door.'

x, y
policeman(x) door(y) open(x, y)
x, y, e
policeman(x) door(y) e: open(x, y) F(e); where F is the future tense

Figure 2.9b. Contrasting PC representations.

Figure 2.9b shows that the tense marker ('will') quantifies over the event ('e'), which contains the verb and its arguments; and, because of this ability to predicate over another predicate (namely the verb), the tense marker provides an example of higher-order predication.

2.4.2. PRONOMINALS. Pronominals (e.g. *I*, *we*, *they*) are a manifestation of linguistic deixis, because they point to individuals in the real world. Take, for example, the sentence 'I like sardines'. *I* is deictic because it points to the speaker of an expression (first person). Similarly, *you* refers to the hearer of an expression (second person), and *he/she/it* refers to an individual or entity outside of the speech act (third person).

By definition, deixis deals with 'terms whose contribution to propositional content depends on the context in which they are used, and their meaning consists in specifying the aspect of context that determines what contribution to content they will make' (Chierchia & McConnell-Ginet 2000:333). Deictic expressions, such as pronouns, 'comprise the set of contextual anchors for deictic reference to speech act participants' (Frawley 1992:280). For example, the pronoun 'I' is context dependent, as it changes depending on the context/index (e.g. it refers to a different person if Mike Manookin says 'I' than if Dave Matthews says 'I'). 'I' is an anchor (Peirce called it the Ground) because it refers to a member of a set. Finally, 'I' refers to the speaker in a speech act, and is thus the deictic referent (Peirce's Logical Interpretant). Figure 2.10b shows the predicate calculus representation of 'I enjoy chocolate.'

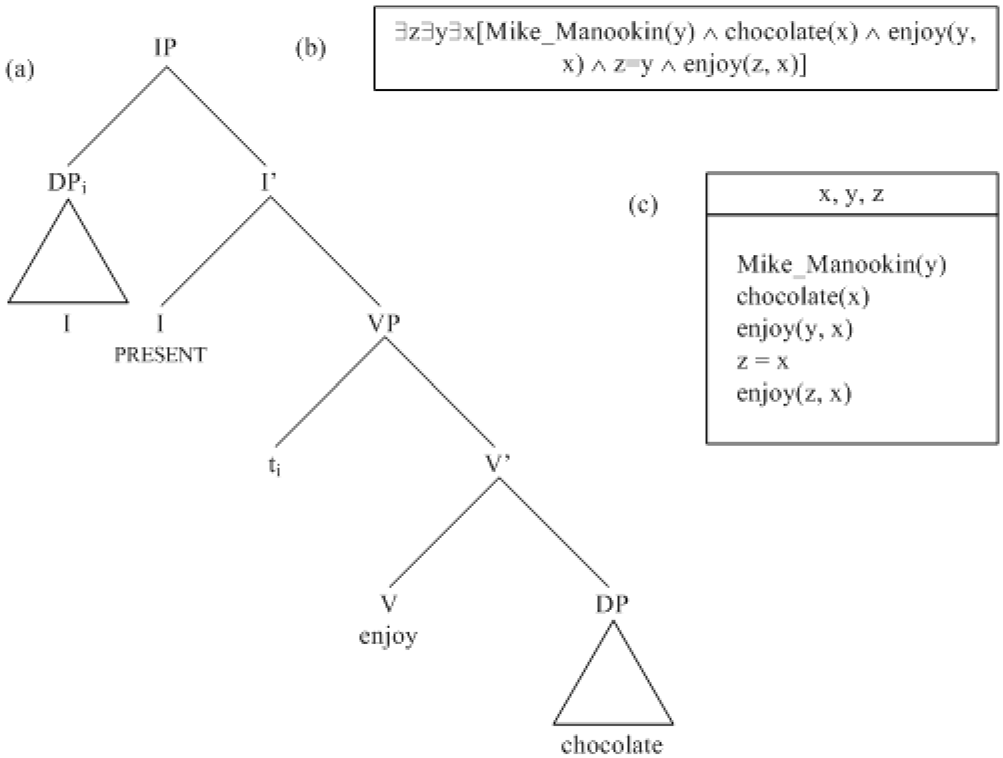


Figure 2.10. The X-bar parse for 'I enjoy chocolate.'

This example reflects the three properties of pronouns just discussed: *z* is the anchor, *Mike Manookin* is the deictic referent, and context relates these two attributes by the operation $z = x$.

Why, then, do autistic subjects often incorrectly mark pronouns for case? For example, autistic subjects often mark pronominal subjects (e.g. 'I sneeze') with the genitive case ('my (or mine) sneeze') or accusative case ('me sneeze'). Case theory in the Government and Binding framework states that nominative case marking ('I') on a subject is assigned by Tense (I^0) to the specifier position of IP after moving from specifier VP position as in Figure 2.11.

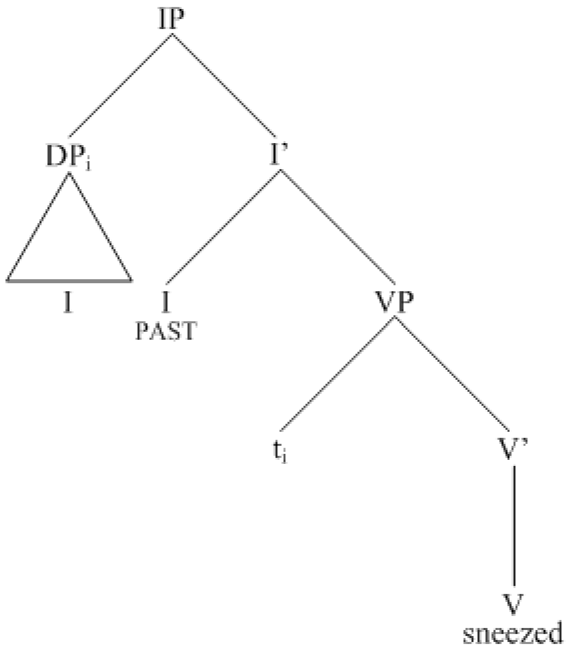


Figure 2.11. X-bar representation of ‘I sneezed’.

If no movement occurs, according to the theory, then the pronominal might not appear in nominative case. Thus, if the pronominal remains in the specifier position of VP, then it cannot receive case from I^0 and thus might be found in any case, as reflected in Figure 2.12. This observation describes case phenomena in several languages, including Russian (Preslar 1998).

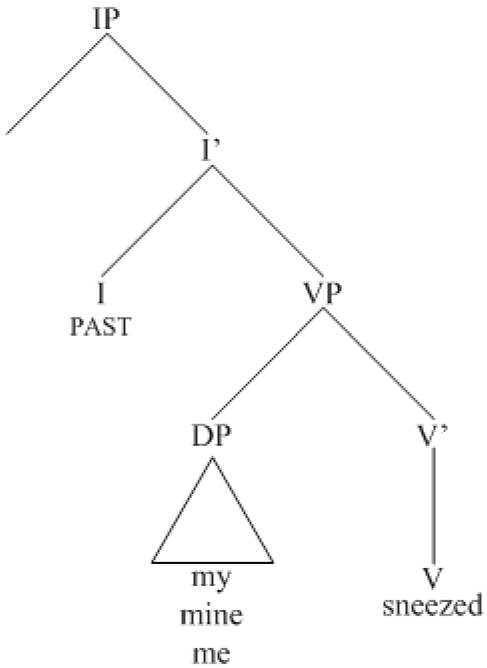


Figure 2.12. X-bar representation of 'my/mine/me sneezed'.

This observation is important, as syntactic movement to higher c-command positions above the VP shell is a way of abstracting scope over verbal predicates. To understand the significance of this point I need to introduce a theoretical approach (Butt & Ramchand 2001) to mapping events from syntax to semantics. According to this approach, an event can be decomposed into a maximum of three subevents: a causing subevent, a caused process, and a caused result state. These subevents are mapped from syntactic structure in the following way: the causing subevent maps from spec-IP, the caused process maps from spec-VP, and the caused result maps from a nominal complement of the V-bar, as demonstrated in Figure 2.13, which is a partial reproduction of Butt & Ramchand (2001).

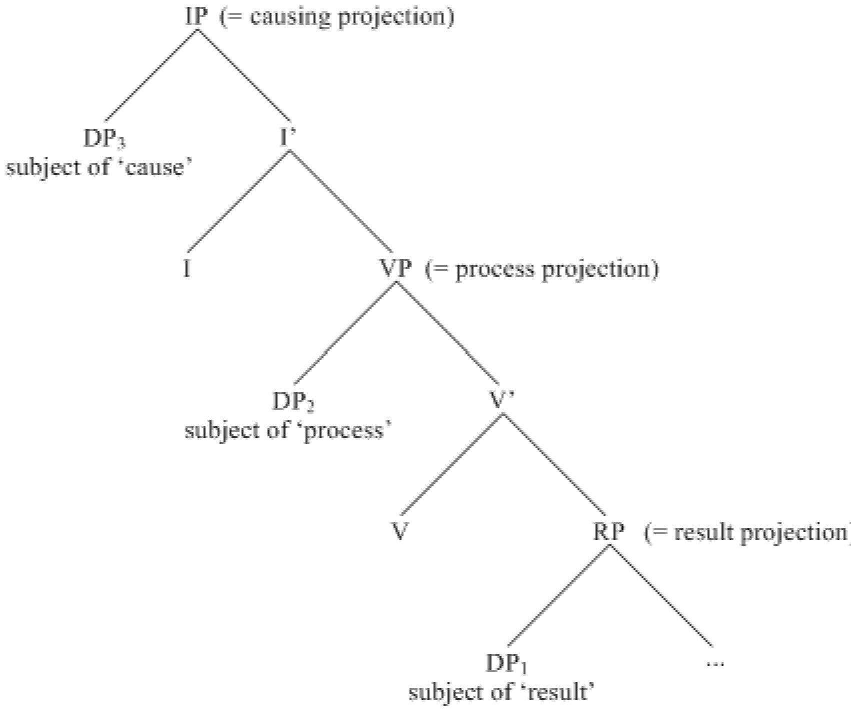


Figure 2.13. Mapping syntactic structure to event semantics.

Butt & Ramchand (2001) note that a subject can be represented in more than one of these positions as demonstrated in traces (argument chains) previously. Figure 2.13 demonstrates that there is a semantic distinction between subjects in spec-VP and spec-IP. Movement of a subject from spec-VP to spec-IP essentially imposes more causal/volitional power on the moved subject. Thus, subject movement that abstracts higher scope over the VP shell is really a metaphor for increasing volition or causal potential.

Consider the sentence: 'Bill gave Betty a strawberry'.

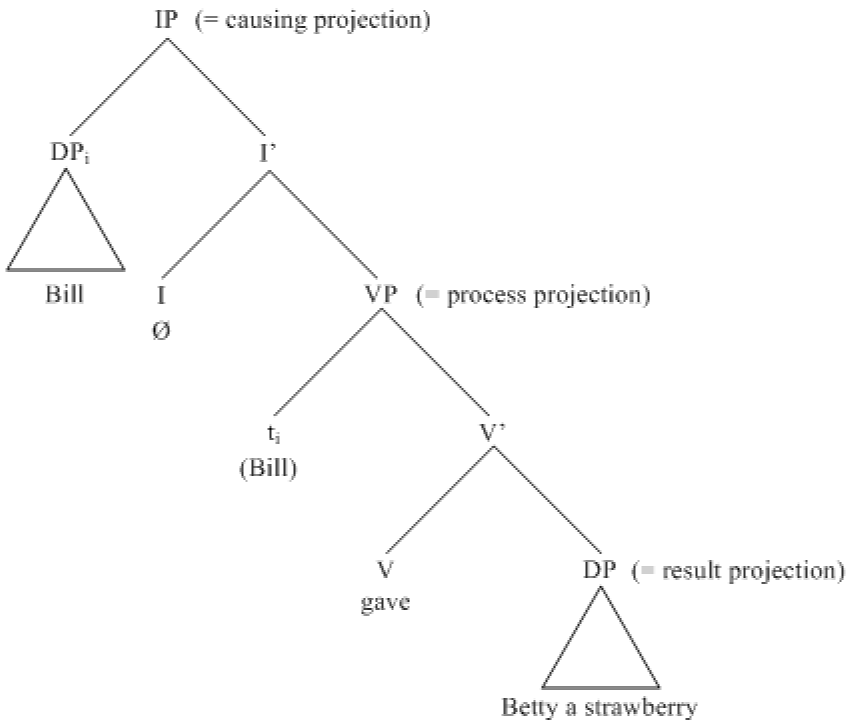


Figure 2.14. Syntactic representation of 'Bill gave Betty a strawberry'.

Figure 2.14 shows that 'Bill' is both the subject (causer) of the event (spec-IP or causing projection) and subject of the process subevent (as in '[Bill's giving Betty a strawberry] amused us'). Also, 'Betty' is subject of the result subevent ('Betty' now has 'a strawberry').

2.5. Autistic syntax and quantification. The literature depicts three major areas of irregularity in autistic syntax: negation, modals, and prepositional syntactic relations. This section addresses each of these three phenomena in terms of semantic mapping.

2.5.1. Propositional negation. The ability to negate a proposition is an important characteristic of language. Propositional negation 'preferentially affects only that part of the proposition whose factual status, assertability, and commitment could be in doubt' (Frawley 1992:391). Thus, a vital aspect of negation is its relationship to quantification. Negation can quantify over arguments internal to the proposition, or over the entire proposition itself.

For example, the negative operator (¬) in, 'I am irrational,' is internal to the proposition (i.e. sentence) since it quantifies over 'rational'.

(2.2) ir-rational
¬(rational)

Internal negation only requires first-order predication as the negative operator applies itself as a predicate of the subject 'rational,' and not another predicate. To contrast, in 'I don't know a crook,' the negative operator holds scope over the entire proposition (i.e. over the verb and all of its arguments), as manifest by Figure 2.15.

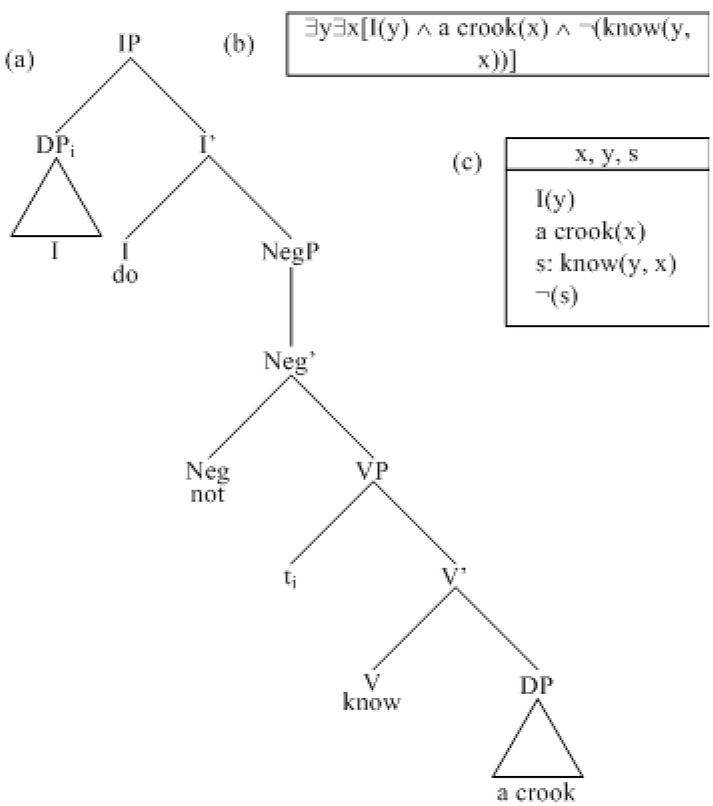


Figure 2.15. X-bar and PC representations of 'I don't know a crook.'

Just as with other types of modality, proper representation of negation requires higher-order predicate calculus.

2.5.2. Modals. Modals (such as *must* and *should*), like negatives, have the ability to quantify over a predicate verb. For example, in the string 'the author must finish the novel,' 'must' quantifies over (c-commands) the verb and all the verbal arguments, as reflected in Figure 2.16.

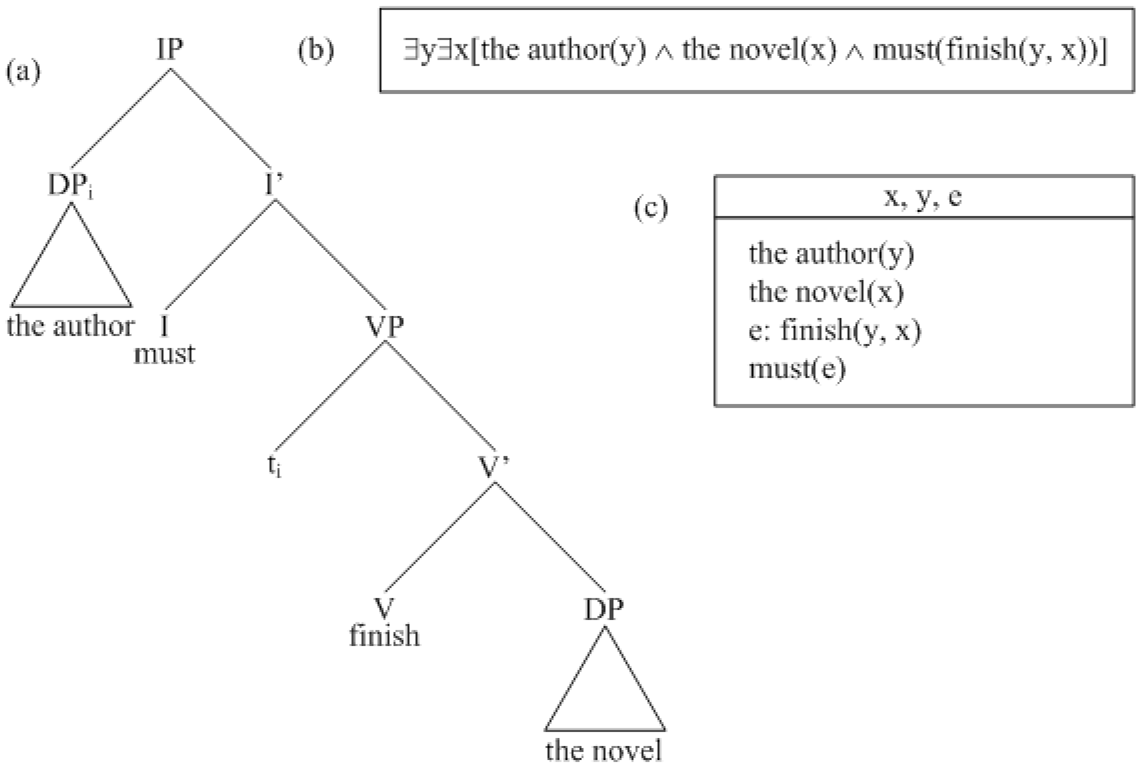


Figure 2.16. The X-bar and PC representations for 'the author must finish the novel.'

In this syntactic representation, 'must' is in the I^0 node—the same place normally occupied by tense. This shows that modalities like 'must' c-command the verb phrase (VP) which contains the verb 'finish' and its internal arguments. Furthermore, in X-bar theory, I^0 assigns nominative case to the NP 'the author,' which is the external argument of the verb 'finish.' The semantic representation in Figure 16b reflects this concept more clearly, as 'must' quantifies over 'finish' and its arguments.

Modals quantify over events and states, and thus quantify over verbs (which predicate events and states) and their arguments. For instance, *must* and *necessarily* quantify over possible situations, whereas *always* and *will* quantify over times (Frawley 1992:385-386).

Modals that denote necessity, such as 'must' and 'shall', do not occur in the autistic corpus, in fact the only modal that occurs with any frequency is 'can'; and when it does occur, it usually materializes in the context of asking permission as in 'Can I have the cardboard?' This use may be a more stereotyped use of the modal, but regardless modals are infrequent in the autistic corpus—a fact that supports previous research on autistic language.

2.5.3. PREPOSITIONAL SYNTACTIC RELATIONS. Syntactically, prepositional phrases generally have two possibilities: they can modify the preceding noun phrase, or the preceding verb phrase. For example, in 'John threw the baseball with seams to the catcher' the first prepositional phrase ('with seams') modifies the noun phrase ('the baseball'), while the second prepositional phrase ('to the catcher') modifies the verb phrase ('threw'). Semantically, this means that a prepositional phrase can predicate over entities, events, or states; entities involve noun phrases while events and states involve verb phrases. Predication is involved in each instance—prepositions predicating over entities use first-order predication, whereas prepositions predicating over events and states involves higher-order predication. This fact is reflected in the syntactic and predicate calculus representations of 'the linguist reads novels with those glasses' (Figure 2.17).

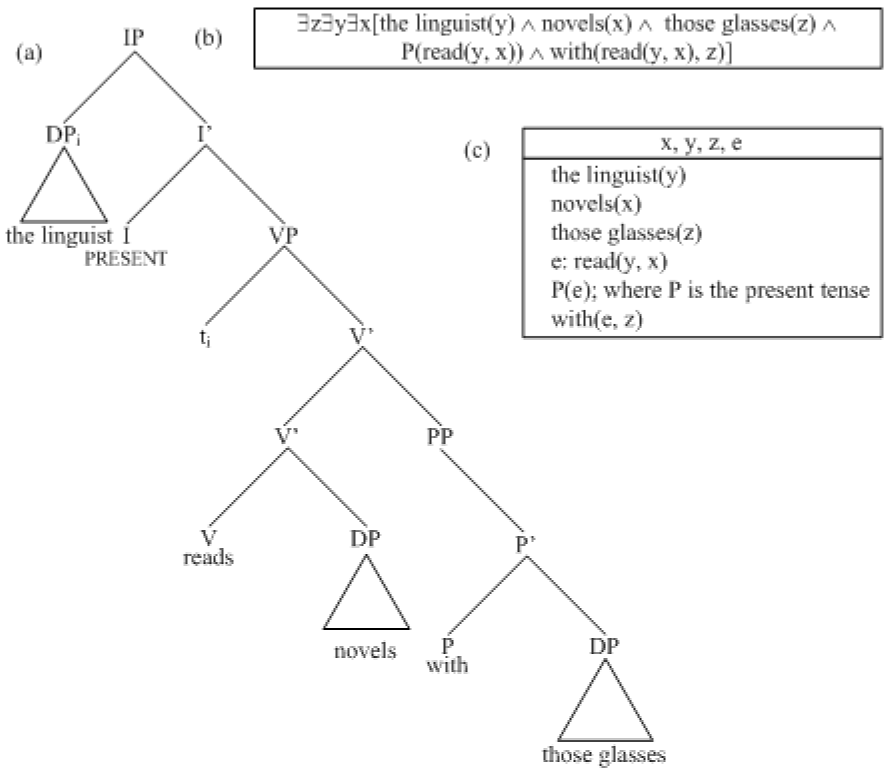


Figure 2.17. X-bar and PC representations of 'the linguist reads novels with those glasses.'

Notice that in this syntactic representation, the prepositional phrase 'with those glasses' attaches as an argument of the verb 'reads'. This means that the prepositional phrase modifies (provides information outside the scope of) the verb, and semantically, this is represented by the preposition 'with' predicating (quantifying) over the event of 'the linguist reads novels'.

Because the preposition 'with' predicates over an event, in this case, this is an example of higher-order predication. To contrast, when a preposition predicates over an entity (ex. the linguist enjoys novels with illustrations), first-order predicate calculus is all that is required, as reflected in Figure 2.18.

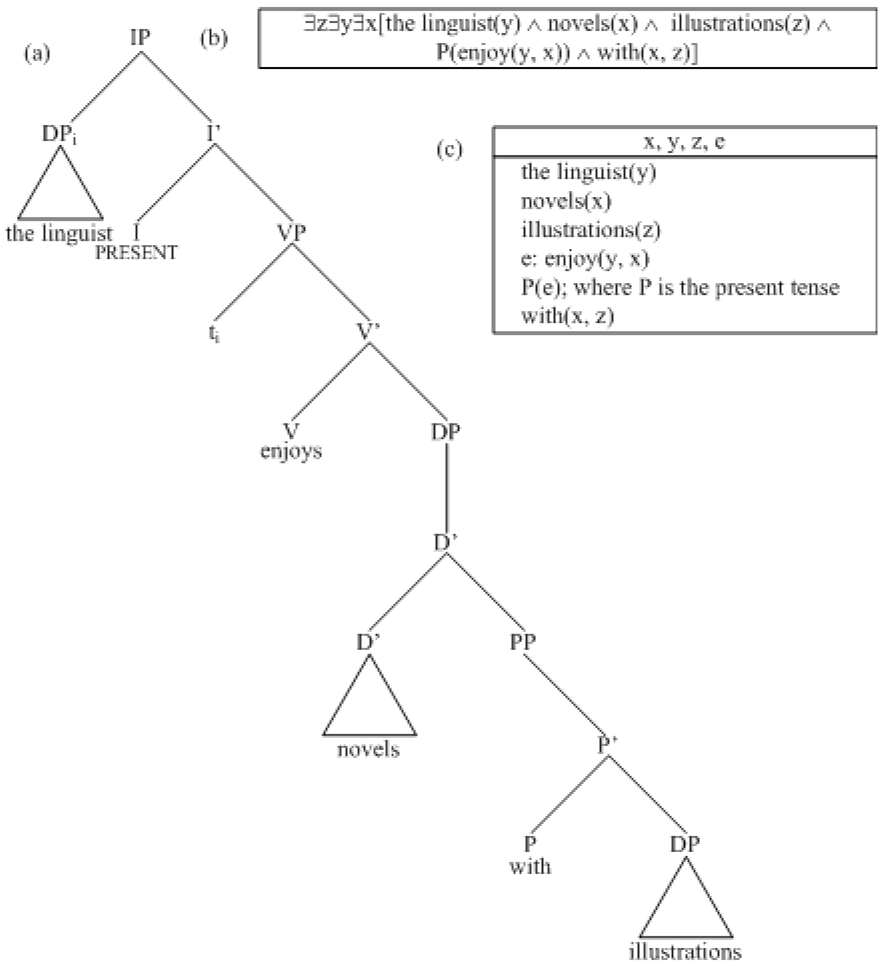


Figure 2.18. X-bar and PC representations of 'the linguist enjoys novels with illustrations.'

According to this model, an autistic person should have more trouble understanding the semantic relation between prepositions predicating an event or state than s/he would with a preposition predicating an entity.

In the autistic corpus I analyzed, a typical use of the preposition 'with' involved nominal scope: 'Give me a sentence with boomergang'. 'With' also occurs in sentences with verbal predication such as 'Go with Phil,' but again, as with modals, prepositions in general were fairly infrequent in the autistic corpus. More work needs to be done to determine which specific types of prepositions autistic subjects struggle with, but this will require a fairly substantial corpus.

2.6. Refinement of hypothesis. This gives me an opportunity to refine my initial hypothesis. From the above analysis, it is clear that autistic language is not deficient in all aspects of quantification. Verbal predication, by all accounts, remains intact. I could extend the hypothesis to include only higher-order predicate calculus operations, but this would not account for misuse of pronouns. The quality that these phenomena share is that semantically they all point out a set or member of a set. Quantifiers like 'might' point out a possible world or circumstance for an event. Likewise, tense and aspect point out the time and status of an event, respectively.

(2.5) The Quantification Hypothesis: The autistic language condition is characterized by a specific linguistic dysfunction: operations that involve quantifying over a verbal event or state, or processes that involve movement from lower to higher subject positions.

This definition is an improvement over the previous version, as it more accurately generalizes the observed phenomena. Visualizing the issue in this way also makes pragmatic and behavioral trends more transparent.

2.7. Autistic pragmatics/behavior and quantification. The vast majority of autistic language research centers on the area of pragmatics. This field of linguistics studies meaning in context, and for this reason is closely related to behavior and semantics.

There are three main pragmatic/behavioral theories of autism: (1) theory of mind, (2) executive dysfunction, and (3) weak central coherence. Many researchers in the field view these theories in competition, but this section shows that all three theories share a common, unifying quality—they all describe autism in terms of a deficit in quantification, although, to my knowledge, no one has described the theories in these terms. This section illustrates that the quantificational deficit hypothesis of autism, as outlined in this thesis, is a unifying generalization describing a common characteristic of autism that holds from the most basic area of language perception, through increasingly complex language structures, to the most complex behavioral interactions.

2.7.1. Theory of mind. 'Theory of mind' is probably the best known theory of autism, and it describes the ability to understand that others have beliefs, desires, and intentions that are different from one's own. This is a capacity that normally develops between the ages of 3 and 5, but which is missing from autistic subjects at any age.

Baron-Cohen (1995) suggests that the mind-reading vital to the theory of mind capacity has a structure—'Agent-Attitude-Proposition[4].' This means that in order to guess at someone's intentions, one must be able to abstract a propositional state from another's actions. So, if I believe that John is upset, it is only because I have abstracted from John's various actions (facial expressions, tone of voice, etc.) that John *might* be upset about something. This is a quantificational inference, as I am supposing that John's frowning and his abrupt tone are qualities of the same state. Perhaps the connection will be clearer if we study this phenomenon in the context of set theory.

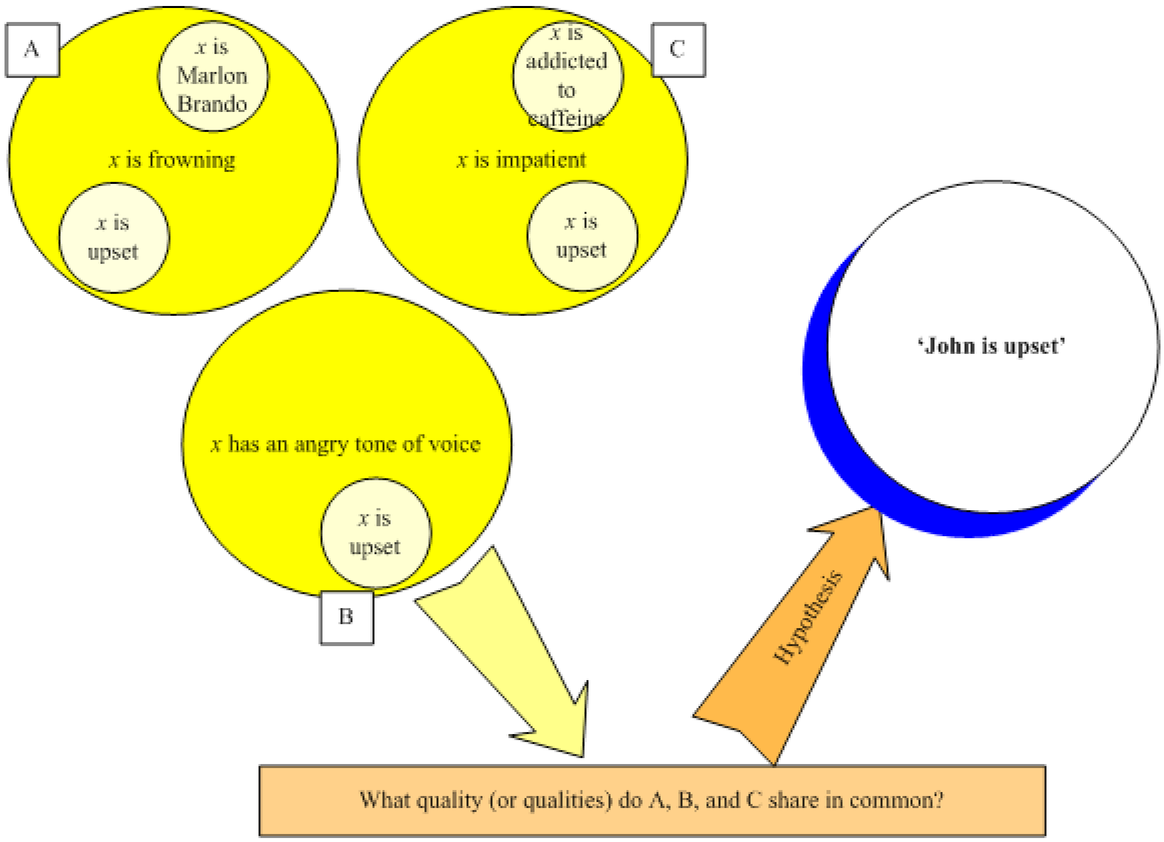


Figure 2.19. A set-theoretic representation of 'theory of mind' inference.

Thus, the mental state of 'being upset' quantifies over the set of its qualities (e.g. frowning, abrupt tone, etc.). Furthermore, in order to believe something about John's mental state, my state of belief must quantify over John's supposed mental state. For example, 'believe' quantifies over the supposed mental state of John in the sentence 'I believe that John wants a drink,' as the predicate calculus representation in Figure 2.20 illustrates.

```
x, y, s
--------------------
I(x)
John(y)
drink(y)
s: wants(x, y)
believe(x, ^s)
```

Figure 2.20. PC representation for 'I believe that John wants a drink.'

In this representation 'I' is the external argument of 'believe,' which quantifies over the event 'John wants a drink' (s), which is John's supposed mental state.

This same concept (quantification) also applies to other aspects of theory of mind such as counterfactual reasoning. Counterfactual reasoning is a type of hypothetical reasoning in which at least one state of affairs (proposition) is deemed false. 'Counterfactual reasoning . . . involves the very sort of monitoring of psychological states for which a theory of mind is needed—the ability to keep track of the scope of a supposition, to differentiate one's actual beliefs from the counterfactual supposition, and to make appropriate modifications in some of one's background beliefs' (Botterill & Carruthers 1999:102).

I find it interesting that Botterill & Carruthers use the phrase 'keep track of the scope of a supposition' to describe the vital process required for successful counterfactual reasoning—a type of hypothetical reasoning[5] (Halpern 1999) which requires the ability to represent and recognize true and false circumstances (models of the world), and reasoning on the basis of the incorrect model (Roese 1997). Thus, counterfactual reasoning negates a proposition,[6] then uses this new proposition and implications that follow from it to understand and deal with a situation.

2.7.2. Executive dysfunction. Executive function describes 'the mental operations which enable an individual to disengage from the immediate context in order to guide behavior by reference to mental models or future goals' (Hughes, et al. 1994).

Autistic subjects show executive dysfunction as evidenced by poor scores on the Wisconsin Card Sort (Ozonoff, et al. 1991; Reichler & Lee 1987; Rumsey & Hamburger 1990; Sandson & Albert 1984), Tower of Hanoi (Ozonoff, et al. 1991), and Tower of London (Hughes, et al. 1994) tasks. I will describe each test briefly. This section will show that the autistic condition is characterized, not by a general difficulty with planning, but by a specific aspect of the planning task—the ability to abstract/quantify over a model.

The wisconsin card sort test. The Wisconsin Card Sort Test (WCST) is performed with a pack of sixty cards, each of which has either a triangle, star, cross, or circle, in one of four colors (red, green, yellow, or blue), and, in some versions of the test, one of four numbers (1, 2, 3, or 4). Each card in the pack is unique. The examiner instructs the subject to put the cards, one at a time, under four sample cards. The tester either approves or disapproves of each card placement by the subject; the subject must use this information (approval or disapproval) to infer the sorting rule. After the subject has determined the correct rule and correctly placed ten consecutive cards, the rule is changed and the subject must reanalyze her/his approach. The required rule sequence for the test is (1) color, (2) form, and finally (3) number. The task is scored by the number of correct strategies inferred with the pack of cards (Saper, et al. 2000:358).

Autistic subjects show strong perseveration during the WCST (Ozonoff, et al. 1991; Reichler & Lee 1987; Rumsey & Hamburger 1990; Sandson & Albert 1984). In other words, they keep putting a card on the wrong stack even when the researcher has already told them that the previous placement (i.e. the previous rule they were using) was incorrect. To explain why autistic subjects have trouble reanalyzing during this task, I will explore the subtasks/subgoals required to successfully accomplish this task.

Let's examine a hypothetical WCST scenario according to the reasoning process involved. There are four cards face up on the table: a blue triangle, a red circle, a yellow star, and a green cross. I must decide what to do with the first card in the deck, a blue star. I have two choices that correspond to the *qualia* of the card itself (blue & star)—I can place the blue star under the blue triangle or the under yellow star.

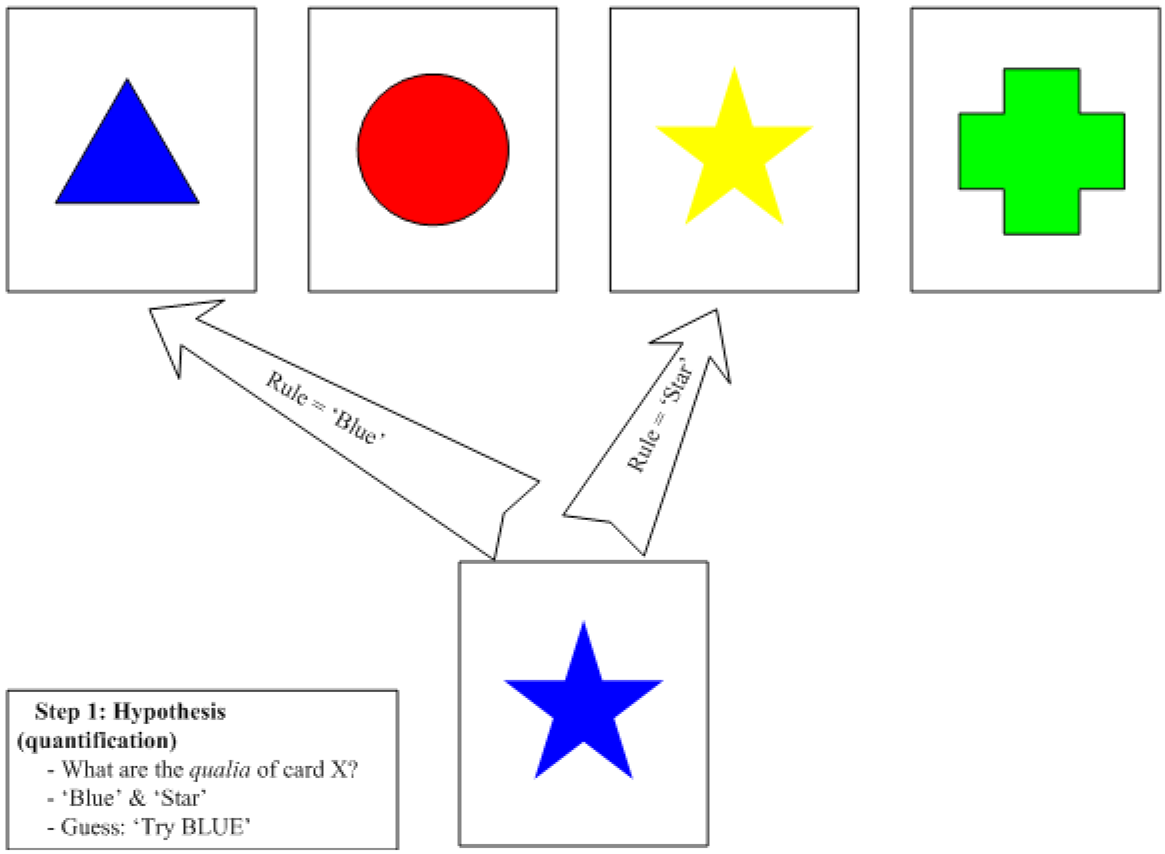
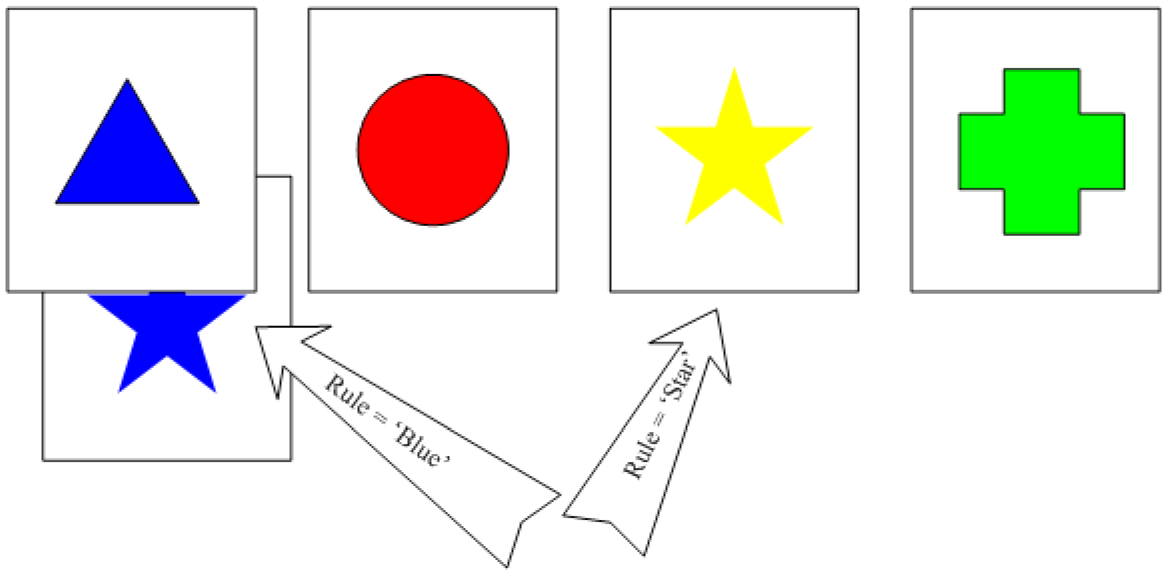


Figure 2.21 walks through the normal steps in the decision-making process for inferring the correct rule for a given instance in the WCST. Card X refers to the card I have in my hand (that I must place) and the test cards are the four cards under which I must place card X. Thus, this is a categorization problem.

RULE$_1$: Each card in this deck has exactly two *qualia*.
RESULT$_1$: The test cards and card X are from the same deck.
CASE$_1$: Card X shares a quality with two of the test cards.
RESULT$_2$: Card X has the qualia blue & star.
RULE$_2$: If the vital quality is blue and I place card X under the blue triangle, then the examiner will approve of this choice.
CASE$_2$: When I placed card X under the blue triangle, there was confirmation.
RESULT$_3$: The vital quality is 'blue.'

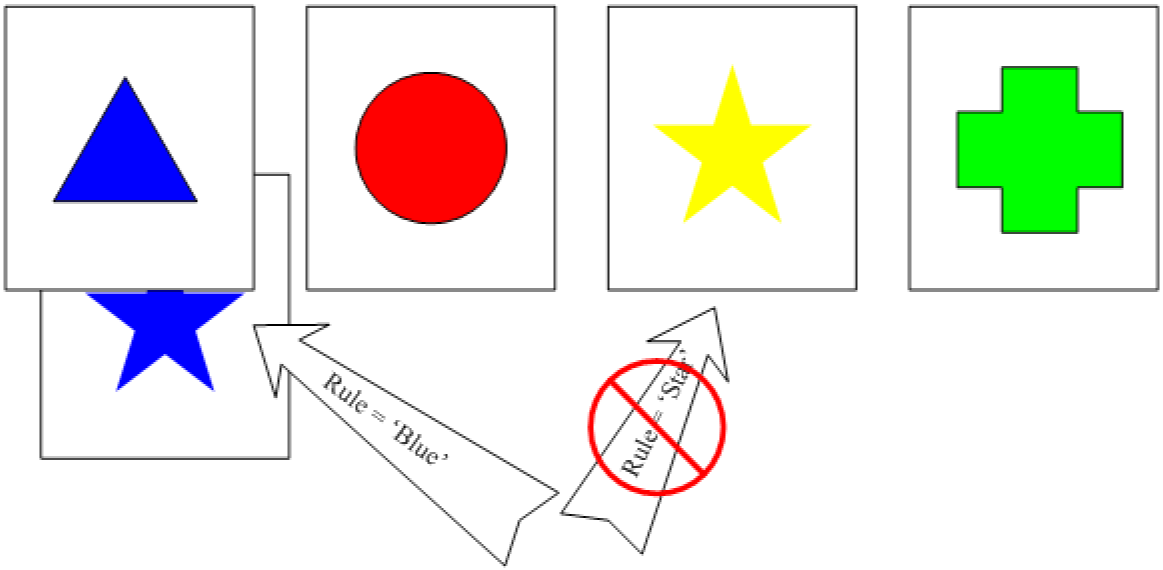
Figure 2.21. Normal steps in inferring a WCST rule.

This first step was a quantification, as I abstracted from the card's *qualia* (the sets to which it belongs) the possible cards which might govern the set to which the card in my hand belongs.



Step 2: Test Hypothesis
- Put card X under the blue triangle
- Confirmation by tester

Next, I must set out an if-then proposition (a deduction). *If* the decisive quality is 'blue' and I put the card under the blue triangle, *then* I expect the investigator to approve of my choice, *else* the quality must be 'star.'



Step 3: Revise Hypothesis
- Guess was correct
- Negate ‘Rule = Star’
- Apply ‘Rule = Blue’ to subsequent choices

Finally, I must run a test to confirm whether my supposed rule is or is not correct. Perseveration in the wrong choice, which is typical of autism, would occur if the initial step were a completely unguided guess. On reanalysis (when I should place the second card down) I would not have determined the rule that governs this case. Thus, misguided perseveration is indicative of behavior that is not goal-directed in nature, which cannot abstract goal-directed guesses from the immediate context.

The tower of hanoi. To administer the Tower of Hanoi task, a researcher gives the subject three pegs (A, B, and C). Three rings—one large, one medium, and one small (respectively, top to bottom)—surround peg A; pegs B and C are empty. The object of the task is to move the discs to peg C so that they arrive in the same order, but only one disc may be moved at a time, and a larger disc cannot be placed on a smaller one.

CONDITION$_1$: rings must be bottom to top, smallest to largest, respectively CONDITION$_2$: cannot move a larger disc cannot be placed on smaller CONDITION$_3$: $C_f = A_i$
RULE$_1$: A_i (in the initial state) has the same *qualia* as C_f (in the final state). RESULT$_1$: $A_i \neq A_f$; $B_i = B_f$; $C_i \neq C_f$; nothing is known about intermediate states. CASE$_1$: Pegs A & C must change state; don't know about B. RESULT$_2$: Ring L can be moved to either B or C. RULE$_2$: If move to B, then C is empty; if move to C, then B is empty. CASE$_2$: When L is on B, condition$_1$ is optimal with respect to C. RESULT$_3$: Moving L to B is the optimal move.

Figure 2.22. Subgoal$_1$: move a ring to uncover a smaller ring.

To solve the Tower of Hanoi problem, one must first decide how to move the largest ring (L). Figure 2.22 reflects this process. In order to solve subgoal$_1$ I must first make a general guess as to what must happen, by abstracting information about this case (subgoal$_1$) from the general *qualia* of the task; thus, rule$_1$, result$_1$, and case$_1$ are all steps in the quantificational reasoning which begins this process.

CONDITION$_1$: rings must be bottom to top, smallest to largest, respectively CONDITION$_2$: a larger disc cannot be placed on smaller CONDITION$_3$: $C_f = A_i$
RULE$_1$: A_i (in the initial state) has the same *qualia* as C_f (in the final state). RESULT$_1$: $A_i \neq A_f$; $B_i = B_f$; $C_i \neq C_f$; nothing is known about intermediate states. CASE$_1$: Pegs A & C must change state; don't know about B. RESULT$_2$: Ring M can be moved to either B or C. RULE$_2$: If move to B, then C is empty; if move to C, then large is on B & medium is on C. CASE$_2$: When M is on B, condition$_1$ is optimal with respect to C. RESULT$_3$: Moving M to B is the optimal move.

Figure 2.23. Subgoal$_2$: move another ring to uncover a smaller ring.

After subgoal$_2$ completes, the final subgoal (subgoal$_3$) begins and ultimately results in successful completion of the Tower of Hanoi puzzle.

CONDITION$_1$: rings must be bottom to top, smallest to largest, respectively CONDITION$_2$: cannot move a larger disc cannot be placed on smaller CONDITION$_3$: $C_f = A_i$
RULE$_1$: A_i (in the initial state) has the same *qualia* as C_f (in the final state). RESULT$_1$: $A_i \neq A_f$; $B_i = B_f$; $C_i \neq C_f$; nothing is known about intermediate states. CASE$_1$: Pegs A & C must change state; don't know about B. RESULT$_2$: Ring S can be moved to either B or C. RULE$_2$: If move to B, then C is empty; if move to C, then L&M on B and S on C. CASE$_2$: When S is on C, condition$_3$ is optimal. RESULT$_3$: Moving S to C is the optimal move.

Figure 2.24. Subgoal$_3$: move the smallest ring (S) optimally.

Figures 2.22-2.24 reflect normal decision processes (or mental states and transitions) necessary to solve this puzzle. These figures are the starting point in understanding why autistic individuals have difficulty with this problem. The mere fact that autistic subjects have trouble solving the Tower of Hanoi puzzle suggests that they are not processing the problem in the same way as a normal person (i.e. they are not traversing the same states as a normal individual). What are they missing?

This process must begin with some doubt or uncertainty. If I am to solve this task, then I must begin with a question: how can I get from my present state (state$_1$) to the desired (goal) state (state$_2$)? This question, in turn, leads to another inquiry: what is the process to get from state$_1$ to state$_2$; what are the transitions? This second question leads me to propose subgoals, which set the process in motion. But in addition to being the beginning of the process, this second question is an example of quantification, as it requires me to posit a sequence and form for each subgoal (i.e. to treat the subgoal as a set and to subdivide this set into subsets).

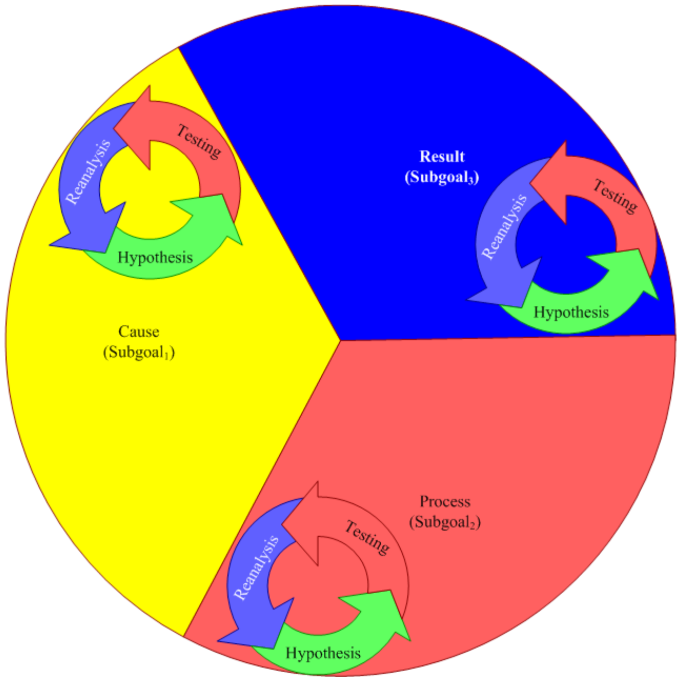


Figure 2.25. Representation of the sub-processes involved in executive function.

Figure 2.25 shows that the executive function has at least two layers of quantification: (1) a layer that separates the goal (e.g. solve the Tower of Hanoi) into distinct subgoals and (2) a layer that splits each subgoal into the process of hypothesis, testing, and reanalysis.

Without this ability to quantify, the process would not be goal-directed, which is what seems to be the case in autism. This explains the significant difficulty that autistic subjects have (versus normal subjects) with planning tasks such as the Tower of Hanoi and Tower of London puzzles.

The tower of london. Hughes, et al. (1994) found that autistic subjects perform poorly on the Tower of London task. This task, like the Tower of Hanoi, relies on three rings and three pegs, but instead of *hearing* the goal (as in the Tower of Hanoi), in the Tower of London task the subject is *shown* the initial and goal states of the rings and pegs (Saper, et al. 2000). The fact that autistic subjects have trouble on both 'Tower' tasks illustrates that their executive dysfunction is not specific to either visual or auditory processing, but is a general deficit.

Unfortunately, no study has looked at the specific points in this task where the reasoning of the autistic subjects begins to break down. This question is vital to evaluating my hypothesis—that the quantificational aspect of these tasks is at fault for the more general failures.

2.7.3. Weak central coherence. The weak central coherence theory of autism was proposed because of theory of mind's inability to explain the exceptionally good performance of autistic subjects on certain visual and spatial tasks, such as block design and object assembly (Happé 1994; Shah & Frith 1993). Frith and Happé (1994) suggest that these discrepancies in the theory of mind are products of weak central coherence, which is defined as 'the normal tendency to integrate local information in the search for global meaning, a tendency to focus on the whole rather than the parts of any stimulus' (Jarrold, et al. 2000). For example, when given a jigsaw puzzle, many autistic subjects are able to solve the puzzle quickly with the pictures facing down (Rimland 1978). In other words, the autistic subjects use bottom-up processing efficiently at the expense of top-down processing—they are not 'seeing the big picture,' so to speak.

So what allows someone to see the big picture when faced with a problem? The answer is quantification. In fact, central coherence is one of the truly lucid examples of quantification. In terms of a jigsaw puzzle, the process is, as previously mentioned, seeing the puzzle pieces as parts (*qualia*) of the entire puzzle, and since the puzzle is a picture, the pieces are individual *qualia* of the overall picture.

When I attempt to solve a puzzle, my thought processes are something like this:

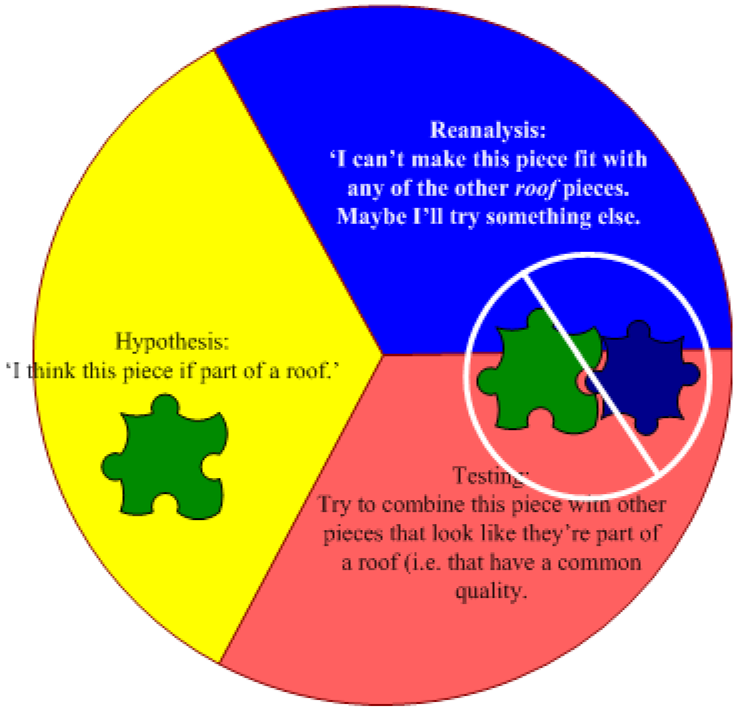


Figure 2.26. Subgoaling involved in solving part of a puzzle.

As with other examples discussed previously, central coherence is initialized by positing a hypothesis (in terms of the big picture, no pun intended), testing that hypothesis, and reanalyzing if the hypothesis tests false (or applying the successful rule to further cases).

CHAPTER 3: HYPOTHESIS INVESTIGATION

Autistic language research must account for the fact that approximately 75 percent of autistic individuals are also classified as mentally retarded (defined as an IQ < 70) while only 3 percent of the general population is so classified (Task Force on DSM-IV: 1994). Language research comparing the language properties of autism and mental retardation can isolate the linguistic abnormalities specific to autism.

3.1. A SYNTAX STUDY. At the end of Chapter 2, I posited my hypothesis: that the autistic language dysfunction is specific to linguistic quantification. In this chapter, I will test this hypothesis by comparing autistic language data with language data from Down's syndrome subjects. This study will specifically address the syntactic structure of these groups by comparing parts-of-speech (POS).

Examining POS can provide important information about syntactic relationships. For example, if a complementizer occurs in the corpus, then we know that a CP structure exists in the sentence. Also, if a modal POS occurs, then we know that an IP is in the sentence. These examples are demonstrated below:

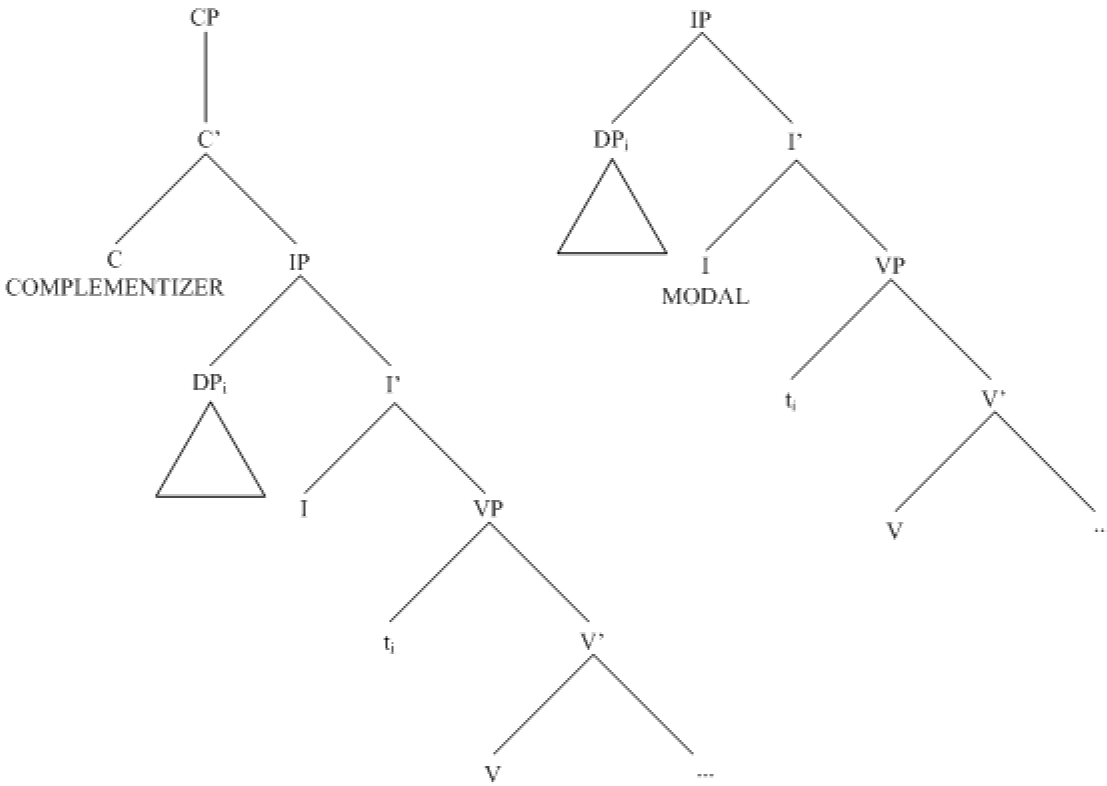


Figure 3.1. Syntactic structures associated with a complementizer and modal, respectively .

Tager-Flusberg, et al. (1990) published a study comparing mean length of utterance (MLU) between six autistic and six Down's syndrome subjects. The subjects were matched for age. Dr. Tager-Flusberg gave me permission to analyze her data for use in my thesis. The data files are transcriptions of interactions that the subjects (autistic or Down's) had with one of their parents[7].

I sought out data comparing autistic and mentally retarded (MR) subjects, because previous research comparing autistic subjects has given considerable evidence for the quantification hypothesis (QH). So, if we have some idea of what distinguishes autistic subjects and normal subjects, and approximately 75% of autistic subjects are technically mentally retarded, then to discover what is uniquely characteristic of autism requires us to understand the difference between autistic and MR subjects.

3.1.1. Method. I performed an analysis of these data to determine whether part-of-speech usage is significantly different between the autistic and Down's subjects. Significant difference is defined as a P value below 0.05 in an analysis of variance (ANOVA). To do this I extracted each subject's utterances from the data file and fed each sentence into a probabilistic part-of-speech tagger (QTAG[8]), developed by Tufis and Mason (1998). QTAG uses Hidden Markov Models (HMMs) to probabilistically determine a word's part-of-speech; therefore the POS of a given word is not 100% certain. QTAG, however, is a widely used tagger, which provides useful generalizations over a large data set. In other words, no part-of-speech tagger will perform perfectly (nor will any human), but the generalizations are strong enough that an analysis of variance will be unaffected by the minor mistakes that such a tagger might make.

I took the output from QTAG and ordered each subject's parts-of-speech (13 total classes) according to frequency of occurrence, then determined the fraction of each subject's words that consisted of a given part-of-speech. ANOVA was then performed on the data and the results were tabulated. The null hypothesis (H_o) for this study is that the average proportion of a given part-of-speech is not significantly different between the autistic and Down's subjects. The alternative hypothesis (H_a), on the other hand, is that these proportions are significantly different.

3.1.2. Results. The results of this analysis are reflected in Table 3.1—P values are bolded. The raw data are provided in Appendix A, at the end of this thesis.

POS	**Df**	**Sum of Sq**	**Mean Sq**	**F Value**	**Pr(F)**
Noun	1	0.0053728	0.00537284	0.6218047	0.4486674
Verb	1	0.0066413	0.00664129	6.156218	**0.03247753**
Determiner	1	0.0007189	0.00071887	0.5197069	0.4874776
Complementizer	1	0.0022772	0.00227717	6.003701	**0.03424342**
Adjective	1	1.707E-05	1.7069E-05	0.5430374	0.4781092
Preposition	1	7.496E-05	7.4956E-05	0.3001649	0.5957957
Adverb	1	4.431E-05	4.4308E-05	2.0571	0.1820208
Quantifier	1	7.412E-05	7.4116E-05	2.365665	0.1550491
Modal	1	5.763E-05	5.763E-05	1.175944	0.3036348
Inflection	1	3.883E-05	3.8826E-05	0.6268374	0.4468911
Negation	1	1.869E-06	1.87E-06	0.1876413	0.6740815

Table 3.1. Results from ANOVA for part-of-speech.

These data show that significant variance between the autistic and Down's subjects only occurs with respect to two categories—verbs and complementizers. Since the P values for these categories are below 0.05, I reject the null hypothesis and conclude that these parts-of-speech are significantly different between autistic and Down's subjects. In other words, the autistic children used verbs far more frequently and complementizers far less frequently than the Down's children. I should note that nouns, adjectives, prepositions, and negation[9] are not informative concerning degree of quantification. That is why I do not comment on them hereafter.

3.1.3. Analysis. Why, then, are verbs more common in autism than in Down's syndrome, whereas the reverse is true for complementizers? Semantically, the defining aspect distinguishing verbs and complementizers is the degree of quantification involved.

Let me illustrate this distinction with a few contrastive examples from the corpus. First, we'll examine the difference in verb use between the autistic and Down's children. The sentence 'I eat a Oreo cookie' is an example of typical transitive verb use in the autistic corpus, whereas the Down's corpus used verbs less frequently; but when verbs do occur in the autistic corpus, they have a similar structure to the autistic constructions. Consider the Down's sentence: 'Horse gonna eat some hay'. Transitive verbs are good examples of basic first-order predication/quantification.

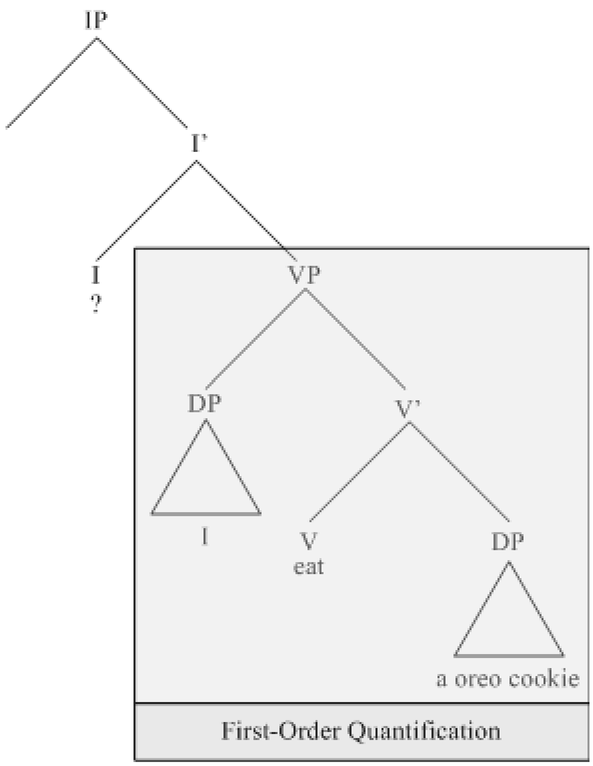


Figure 3.2. Syntactic representation of 'I eat a Oreo cookie'.

In this example, everything c-commanded by the specifier of the VP participates in first-order quantification. There is a '?' mark in I^0, as it is unclear whether 'eat' is tensed (this is also unclear from context in the corpus). This set diagram illustrates this point.

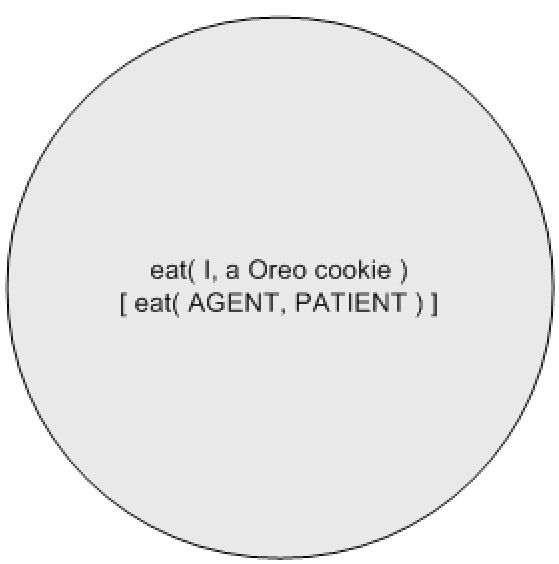


Figure 3.3. Set diagram of 'I eat a Oreo cookie'.

Here, the transitive verb 'eat' predicates two thematic relations: agent ('I') and patient ('a Oreo cookie'). This type of structure does not require partitioning of the set (={eat}) in any way. Thus, the assumption of this study is that a significantly lower frequency in verb use by Down's children points to a corresponding decrease in first-order predication.

Complementizers, however, involve higher-order predication (quantification). Consider this sentence from the Down's corpus: 'We have to talk about our pictures when we go skiing'. Here, the complementizer 'when' joins (and relates) two sentences.

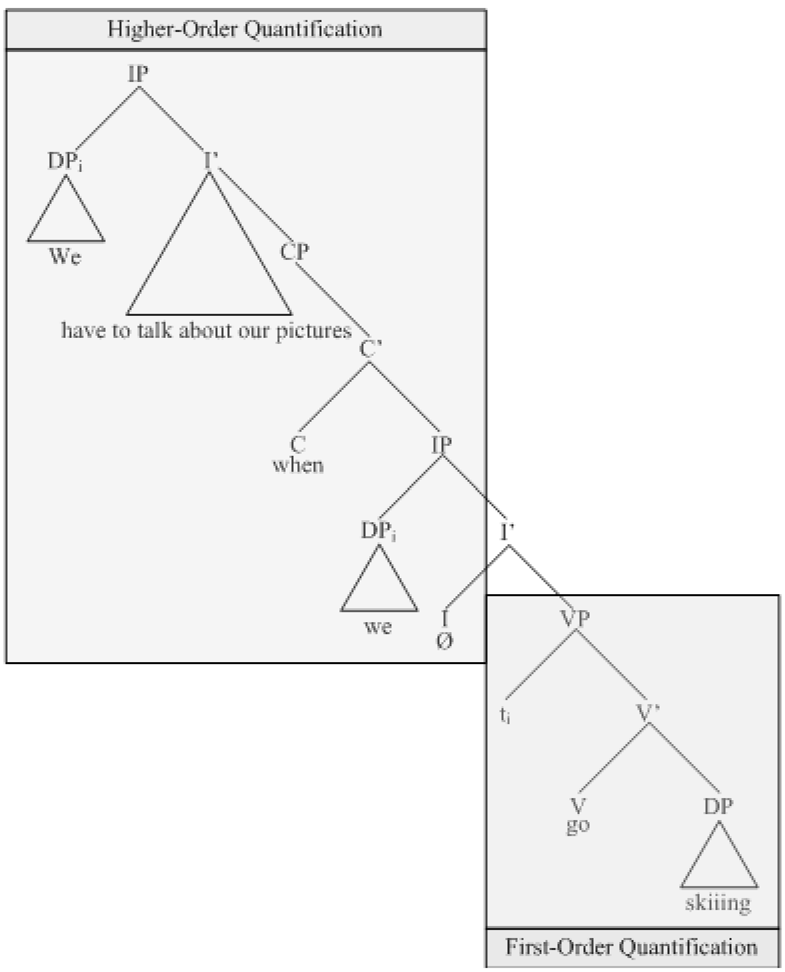


Figure 3.4. Representation of 'we have to talk about our pictures when we go skiing'.

The complementizer 'when' c-commands the lower VP and also creates a logical dependency relationship where 'we go skiing' implies 'we have to talk about our pictures'. This set-subset relationship is reflected below:

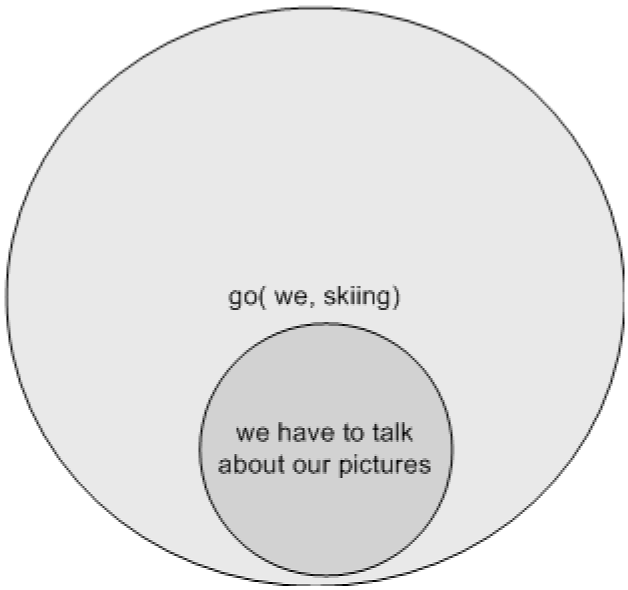


Figure 3.5. Set-subset diagram of 'we have to talk about our pictures when we go skiing'.

Thus, 'we have to talk about our pictures' gives us information about 'we go skiing' such that 'go' is no longer simply a two-place predicate that assigns two thematic roles (roles received by 'we' and 'skiing'). The autistic children used complementizers far less frequently than the Down's kids, and when complementizers do occur in the autistic corpus, they often have a different form. Consider this sentence taken from the autistic corpus: 'I wonder when I'll have chocolate milk'. These conjoined sentences relate to each other in the following way:

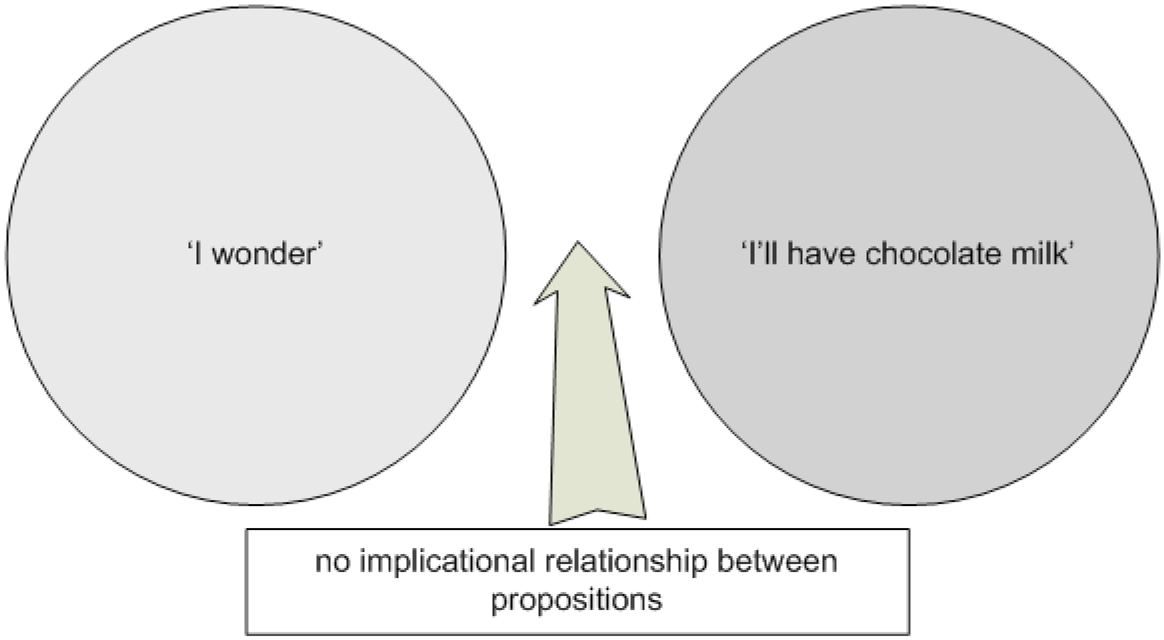


Figure 3.6. Set-subset diagram of 'I wonder when I'll have chocolate milk'.

This figure shows that there is no logical implication between the propositions 'I wonder' and 'I'll have chocolate milk' (i.e. 'I'll have chocolate milk' does not imply 'I wonder').

I should note, or rather reiterate, that the data presented in Chapter 1 show that autistic subjects are impaired compared to normal controls in quantifier, adverb, modal, inflection, and negation use. This fact is probably not apparent from Table 3.1 because the Down's subjects also have trouble with these categories; these data do, however, illustrate the defining distinction between autistic and Down's syntax: **the degree of quantification**. Compared to their autistic counterparts, Down's subjects struggle with all levels of predication (first-order and higher), whereas, semantically, the autistic language deficit is specific to higher-order predication (second-order and higher). Figure 3.7 compares the average frequency of first-order (verbal) predication and higher-order (complementation, adverbial, quantificational, modal, and inflectional) predication between the Down's and autistic groups.

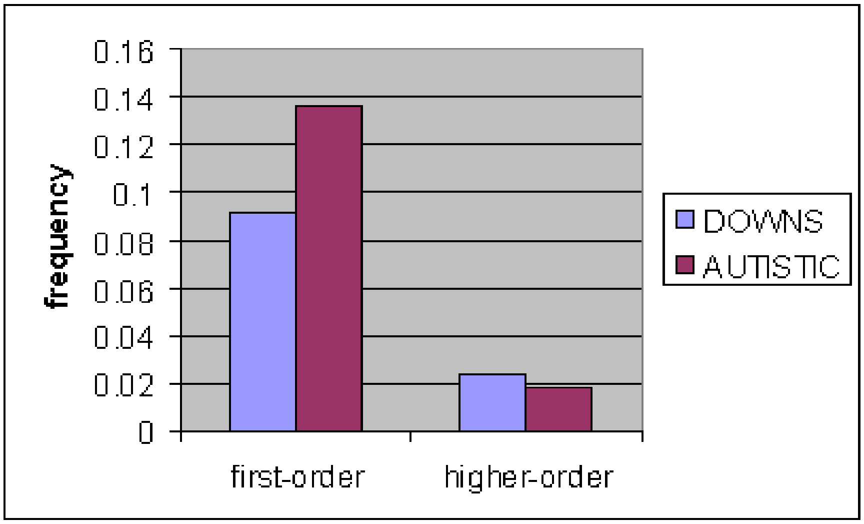


Figure 3.7. Comparison of predication levels between Down's and autistic subjects.

Figure 3.7 shows graphically the distinction illustrated in Table 3.1. First-order predication is significantly more functional in the autistic subjects, but higher-order predication is, as a whole, comparable between the groups—a fact which further supports my hypothesis.

Furthermore, I predict that, given a larger data set, other differences will emerge. For example, adverbs (P = 0.182) and quantifiers (P = 0.155) should more closely approximate a 'P' value of 0.05 as there will be a larger corpus to analyze. Modals, inflection, and determiners should do the same.

3.1.4. Conclusion. These new findings not only support, but characterize, the observation that 'there does not appear to be a global language deficit in autism that affects all aspects of language functioning' (Tager-Flusberg 1981:52). Indeed, the language dysfunction characteristic of autism is not global, but rather specific to a particular type of language operation—higher-order predication or scope abstraction.

CHAPTER 4: DISCUSSION

The data in Chapter 3 introduce two questions: (1) how do these findings relate to the observation that autistic language acquisition is slowed, and (2) what are the possible neurobiological processes that are interrupted in autism? This chapter addresses these questions, gives conclusions to the thesis, and provides direction to future research in this area.

4.1. Autistic language acquisition and the quantification hypothesis. Autistic children show a general slowing in their ability to acquire language (Prizant 1983). Prizant suggests that language development ideally involves a transition from *gestalt* methods (i.e. parroting/mimicking things that they hear) to analytic learning. In analytic acquisition children begin to abstract generalizations about how language is used. For example, they start to realize that the word 'toy' is not restricted to their experience with toys, but that 'toy' can denote something outside of their experience (like 'that big boat is my dad's toy'). In other words, during analytical language acquisition the child begins to realize that her/his representation of the world may differ from other world views. This process is analogy or hypothesis.

In normal children, *gestalt* acquisition peaks at about 30 months of age (Lovaas 1981), as reflected in their prominent use of echolalia and pointing. Soon after 30 months, these children begin to use more analytical/analogical methods, which results in an increasing development of spontaneous language.

Autistic children, however, are often delayed in their transition to spontaneous speech, and many never advance past echolalic language (if they ever progress to the use of echolalia). Autistic children also show periodic declines during language acquisition as demonstrated by drops in MLU (Tager-Flusberg, et al. 1990) and declines *gestalt* language use (Prizant 1983). Why do these declines occur?

Gestalt methods (e.g. echolalia) also decline in normal children as the utility of 'stereotyped' language constructions/expressions decreases. This decline, however, is accompanied by a corresponding increase in analytical language (Prizant 1983). The quantification hypothesis (QH) predicts that declines may occur in autistic *gestalt* language, just as it does in normal children, but there will not be a corresponding rise in analytical language; and, indeed, this is observed (Prizant 1983).

The QH predicts that analytical language will be delayed or absent autistic subjects, as this method of learning requires quantification. Quantification is vital to analytical learning methods, which require a dynamic model of the world.

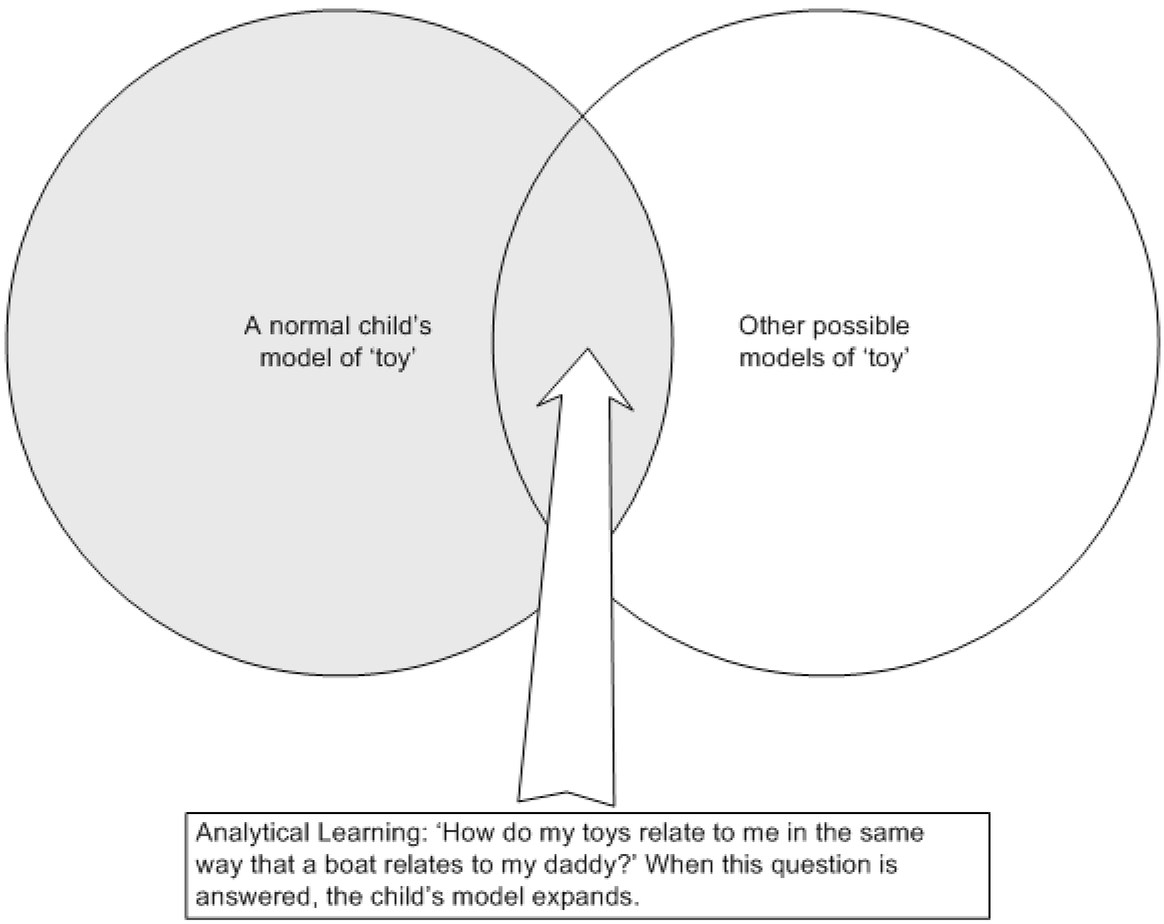


Figure 4.1. Diagram of analytical language learning.

Figure 4.1 demonstrates that as the child participates more in analytical learning, her/his model of the world expands to encompass more of the possible models of a word, concept, etc. Analytical learning is thus a form of quantification, as it introduces new information (e.g.

'my toys are fun; my daddy thinks his boat is fun') that brings about a reanalysis of the child's model. This same process is involved in understanding metaphor.

An autistic child's model, since s/he is restricted to *gestalt* methods, is limited—s/he will be unable to expand her/his model, caused by an inability to understand that other models are possible, as illustrated in Figure 4.2.

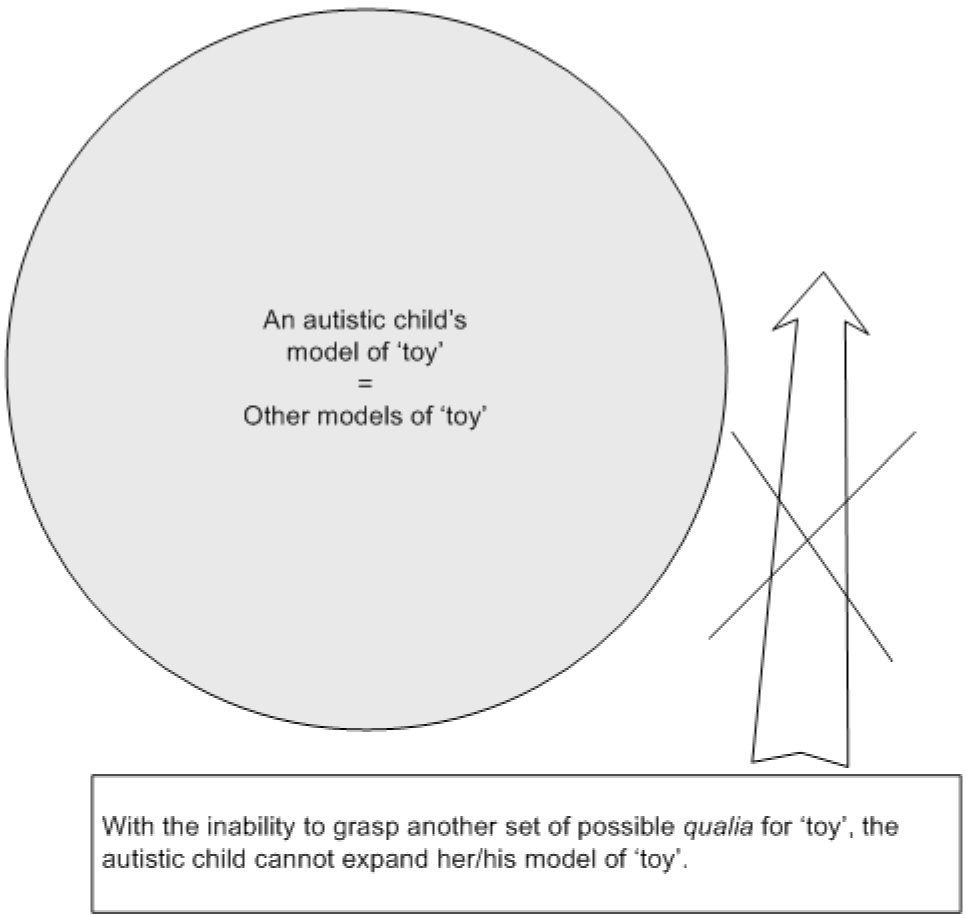


Figure 4.2. Diagram of language learning restricted to *gestalt* methods.

Limiting the mind in this way (i.e. autistic models are not dynamic) results in a decreased ability to reanalyze and limits language and behavior to stereotyped constructions/static models.

4.2. Neurobiological implications of the QH. Now that we have the beginnings of a single, unified theory to describe the linguistic and behavioral characteristics of autism, the next question to ask is whether there is neurobiological data that suggest a possible etiology (or etiologies) for the autistic condition. This question is not easily answered, as psycholinguistics/neurolinguistics has done little work to test the more complex linguistic theories (like predicate calculus, quantification, etc). As a result, practically nothing is known about how the mind/brain deals with quantification. What, then, can we learn about autism from the QH?

It is clear from language philosophers that quantification is a function of 'higher' (perhaps the 'highest') cognition, and such processes are often associated with the frontal lobes. Research, for example, has strongly implicated the frontal lobes in executive function (Robbins 2000). Some researchers also feel that 'theory of mind' development came about in humans from increased volume/connectivity in the frontal lobes (Stuss, et al. 2001; Bird, et al. 2004).

Bauman & Kemper (1985) studied the brain of a postmortem 29-year-old autistic subject and found that, compared to a normal control subject, several brain areas were abnormal in the autistic man: the hippocampus, subiculum, entorhinal cortex, septal nuclei, mamillary body, amygdala, neocerebellar cortex, roof nuclei of the cerebellum, and inferior olivary nucleus. Another study showed a decrease in dendritic branching in the CA1 and CA4 regions of the hippocampus (Raymond, et al. 1989).

Fine, et al. (2001) studied a subject B.M. who had damage to the left amygdala, as this structure has been implicated in 'theory of mind' function. By adulthood, B.M. had been diagnosed with schizophrenia and Asperger's syndrome. These researchers tested B.M.'s executive function (planning, etc.) and 'theory of mind' abilities and found that these functions are impaired versus normal people. For details on the findings of this study see Appendix B.

Abnormal histology in the amygdala, hippocampus, and entorhinal cortex suggests that people with autism should suffer from decreased working memory capacity and the evidence for this is considerable (Hughes, et al. 1994; Pennington & Ozonoff 1996; Bennetto, et al. 1996; Ciesielski & Harris 1997; Minshew, et al. 1997).

Research has also implicated working memory in executive functions such as planning and decision making—functions that are impaired in autism (Carpenter, et al. 2000). Recent studies show that brain areas traditionally associated with working memory (generally the medial-temporal lobe structures) work with cortical areas to modulate working memory phenomena. These cortical areas include the left frontal gyrus, superior parietal lobes, cingulate gyrus, and occipital cortices (Baker, et al. 1996; Osaka, et al. 2004).

Luna, et al. (2002) used fMRI to study spatial working memory in autistic subjects, and found that autistic subjects showed decreased activation in the dorsolateral prefrontal cortex and posterior cingulate gyrus versus normal controls.

This neuroscience research combined with the quantification hypothesis provides a unique insight into the autistic condition. The neuroscience data point to disturbances in the neural structures that mediate working memory and the quantification hypothesis actually supports this conclusion: quantification *should* demand more working memory space than non-quantificational operations.

Linguistic and behavioral operations that involve quantification require greater working memory resources, as more variables are involved—quantification operations require temporary memory storage of *qualia* before a hypothesis concerning the association of those *qualia* can be posited. For example, a 'theory of mind' task like the one in Figure 2.19 requires (1) temporary storage of John's *qualia* (frowning, angry tone of voice, impatient), (2) retrieval (from long-term memory stores) and temporary working memory storage of associations those *qualia* have with mental states, and (3) working memory must be allocated to posit possible associations between John's observed *qualia* and his possible mental states.

With this evidence for disruption of working memory in autism, the real question is what the abnormal areas share in common, especially with respect to late neural development.

4.3. Conclusion. Throughout this thesis, I have attempted to describe and, to some degree, explain the nature of the autistic language deficit. I have posited a new hypothesis of autistic language from my observations of previous research, and I have tested this hypothesis with my own research. Hopefully, this thesis has provided a foundation which will guide future investigations into the nature of autistic cognition.

The theoretical and experimental tools are at our disposal to unravel the complexities of autism into a single, unified theory—a theory which can eventually identify the etiology of autism and perhaps provide a cure. A unified theory of autism will require the use of theoretical and experimental tools in concert; experimental methods alone are simply stabs in the dark, and theory devoid of empirical tests is pure conjecture. Sadly, many investigations rely on one of these methods to the exclusion of the other.

4.3.1. Contributions to the study of autistic language.

1. I have analyzed past research and recognized, for the first time, a common, specific characteristic that, with the publication of this thesis, could greatly increase general understanding of autistic language.

2. I have drawn a correlation between behavioral operations (like planning and counterfactual reasoning) and linguistic functions (such as tense marking, modality, negation, and prosody)—an observation which, to my knowledge, has not been made before.

3. I have tested this hypothesis for validity with syntactic and morphological analyses.

4. I have provided the first generalized and comprehensive analysis of autistic language/behavior.

4.4. Further research. The hypothesis outlined in this thesis must be systematically tested for validity, and this testing should first proceed in three particular areas of language—phonology, morphology, and syntax. Studies in this area should first test autistic against normal subjects, then autistic versus mentally retarded subjects to determine what properties are truly unique to autism.

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APPENDIX A

Data from the POS study. Appendix A provides some of the data from the POS study in Chapter 3. Each subject's data is listed with frequency of POS occurrence on the left and POS on the right.

A.1. Autistic subject data.

A.1.1. Brett.

5084 noun
1420 verb
1158 detr
521 comp
496 prep
334 adjt
260 modl
200 infl
138 advb
76 quan
26 nega

A.1.2. Jack.

3977 noun
852 verb
425 detr
302 comp
262 prep
240 adjt
149 infl
115 advb
101 modl
29 quan
14 nega

A.1.3. Mark.

5891 noun
701 verb
376 detr
310 prep
267 adjt
171 comp
87 nega
77 quan
66 advb

42	modl
22	infl

A.1.4. Rick.

3412	noun
914	verb
756	detr
152	adjt
141	comp
119	prep
87	advb
63	quan
59	modl
21	infl
13	nega

A.1.5. Roger.

3640	noun
1115	verb
675	detr
368	comp
249	adjt
183	prep
144	modl
98	advb
73	infl
39	quan
5	nega

A.1.6. Stuart.

1438	noun
206	verb
37	adjt
34	comp
29	modl
27	detr
23	quan
21	prep
18	advb
1	infl
0	nega

A.2. Down's subject data.

A.2.1. Billy.

5330	noun
759	verb
452	detr
338	comp
270	adjt
127	advb
124	prep
111	quan
60	modl
40	infl
7	nega

A.2.2. Charles.

1528	noun
101	comp
61	verb
56	adjt
50	quan
43	detr
26	advb
7	prep
5	modl
2	infl
0	nega

A.2.3. Jerry.

5065	noun
846	verb
840	detr
736	comp
345	prep
231	adjt
108	advb
103	quan
83	modl
63	infl
44	nega

A.2.4. Kate.

1861	noun
360	verb
229	detr

122	comp
118	prep
83	adjt
55	modl
41	advb
31	infl
16	quan
2	nega

A.2.5. Martin.

4920	noun
645	comp
398	verb
349	detr
213	adjt
127	advb
106	prep
98	quan
84	modl
30	nega
5	infl

A.2.6. Penny.

3350	noun
618	verb
432	detr
369	comp
243	prep
153	advb
130	adjt
100	modl
83	infl
46	quan
16	nega

APPENDIX B

The findings of a study concerning B.M. Appendix B provides a detailed description of the findings of Fine, et al. 2001 concerning a subject, B.M. with damage to the left amygdala. This study shows many strong correlations between B.M. and the symptoms of autism, suggesting that these symptoms may also be attributed to amygdala damage.

B.1. Fine, et al. 2001.

Executive function was determined by three criteria: 'inhibition (the ability to suppress a habitual response), intentionality (the creation and maintenance of goal-related behaviors), and executive memory (temporal sequencing)'.

One of the tasks measuring inhibition was the Stroop task (Stroop 1935). In one version of the Stroop task, the subject sits in front of a computer screen and words written in different colors are displayed, one at a time, on the monitor; the subject then pronounces the word as quickly as possible. For example, if the word 'green' were displayed on the monitor, then the subject would pronounce the word. The word 'green' might be highlighted in any of several colors, and the accuracy and reaction time are recorded by the investigator. Notice that the difficulty of correctly pronouncing the word increases when the word is displayed in a different color than what the word represents.

One of the intentionality tests administered to B.M. was the 'Tower of London' task. In this task the subject is given three pegs with an arrangement of three different-sized rings in a configuration. The subject is then given a picture of the goal configuration and the time and number of steps are recorded for the subject to get to that goal state. This effectively assesses a subject's ability to create and follow a plan in achieving a goal.

Executive memory describes the ability to shift attention from one line of thinking to another. The Wisconsin Card Sort Test (WCST) is performed with a pack of sixty cards, each of which has either a triangle, star, cross, or circle, in one of four colors (red, green, yellow, or blue). Each card in the pack is unique. The examiner instructs the subject to put the cards, one at a time, under four sample cards. The tester either approves or disapproves of each card placement by the subject; and the subject must use this information (approval or disapproval) to infer the sorting rule. After the subject has determined the correct rule and correctly placed ten consecutive cards, the rule is changed and the subject must reanalyze her/his approach. The required rule sequence for the test is (1) color, (2) form, and finally (3) number. The task is scored by the number of correct strategies inferred with the pack of cards (Saper, et al. 2000: 358). In this way the WCST assesses a subject's ability to reanalyze in the midst of ever-changing circumstances.

'Theory of mind' was assessed through false belief, joke comprehension, and non-literal utterance comprehension tests. In false belief tasks a subject is asked to predict the purpose of a story character's actions based on the character's erroneous beliefs. For example, a subject might be told that a character 'Josh' thinks that the milk is in the refrigerator, but the subject knows that Josh's mom moved the milk to the cupboard. The interviewer then asks the subject where Josh will go to look for the milk. The subject's success at this task is dependent on her ability to 'put herself in Josh's shoes', an ability referred to as 'theory of mind'.

In joke comprehension tests the subject is given cartoons, which, to be properly understood, require an awareness of the mental states of the characters.

A non-literal comprehension task tests the subject's ability to understand sarcasm. This task is relevant, as it requires the ability to grasp the speaker's thoughts/intentions. 'For example, the listener can only reject the literal interpretation of "You're looking smart tonight, Frank" if the hearer knows that the speaker thinks that Frank looks scruffy'. If the listener/subject takes the speaker's thoughts/mental states into account, then she will correctly comprehend the non-literal/sarcastic nature of the utterance, but if the subject does not grasp the speaker's mental states, she will interpret the speaker's utterance literally.

B.M. performed well on executive function tasks, but poorly on 'theory of mind' assessments, which suggests that the amygdala is not solely responsible for executive function, but is responsible for 'theory of mind' abilities.

ENDNOTES

[1] $\Delta P = 2(\log(\text{frequency}))$
[2] To learn more see *The Stanford Encyclopedia of Philosophy* (http://plato.stanford.edu/contents.html).
[3] The CHILDES database is available at http://childes.psy.cmu.edu/.
[4] This structure shares remarkable similarities to the basic structure of propositions in Intentional logic/ Montague semantics, which combines Modal logic with 'propositional attitudes' (ex. believe that p, hope that p, etc.). These similarities underscore the usefulness of semantic theory in describing cognitive phenomena.
[5] For more information on hypothetical or abductive inference, see Peirce 1931-1958:2.624.
[6] See Section 2.5.1 for more about negation and quantification.
[7] These data are available from the CHILDES website (http://childes.psy.cmu.edu/).
[8] For more information or to download QTAG (Version 3.1), see http://web.bham.ac.uk/o.mason/software/tagger/.
[9] Prepositions and negation because they can c-command either a verb or a noun.