The Role of the Verb in the Development of Syntax: Evidence from the Structural Priming Paradigm

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Abstract

In recent years, researchers have tended to use structural priming to distinguish between the core predictions of nativist and constructivist theories of syntax acquisition. Although this has been useful for our understanding of what early syntactic knowledge is like, this focus on children's initial representations, rather than on the process of development, means that it is still unclear how children's syntactic knowledge becomes adult-like. To address this issue, this thesis used structural priming to investigate the role of the verb in the development of syntax. In particular, the present work explored how two lexical effects - verb overlap and verb bias – influence structure choice in children and adults for dative and transitive structures. A number of conclusions were drawn: First, the present work revealed there to be a complex relationship between knowledge about syntactic structure and knowledge about verbs; children as young as three have already formed abstract representations of the dative structure, but have also already begun to learn the syntactic preferences of dative verbs. Thus, it was concluded that neither nativist nor constructivist theories can fully explain the abstract and lexical patterning of children's early syntactic knowledge. Second, the findings showed that experience with verbs is important for the strengthening of verb-structure links across development. Third, the present work indicated that adults seem to track the frequency with which verbs occur in their syntactic structures, and that this knowledge can affect the way in which these syntactic representations are stored and activated. The implications of these findings for theories of syntactic development are discussed, and future directions for research are considered.

Section 1: Review

Chapter 1

How do we develop adult-like syntactic representations? An introduction to theories of syntax acquisition and development

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1.1. Thesis introduction and outline

A well-known effect in language is that speakers tend to echo the syntactic structure of the sentences that they have recently encountered - an effect known as *structural priming*. Over the past few decades, the findings from structural priming studies in adults have provided insight into the nature of adult syntactic representations, and have been instrumental in shaping theories of sentence processing. More recently, researchers have used structural priming to investigate the nature of children's early syntactic knowledge. This work, however, has tended to focus on distinguishing between early abstraction accounts of syntax acquisition - which argue that children's syntactic representations are abstract from early on in the acquisition process (e.g., Gertner, Fisher & Eisengart, 2006; Hirsh-Pasek & Golinkoff, 1996), and lexical constructivist accounts which argue instead that these representations are initially built around concrete, item-specific schemas, but gradually become abstract through a process of learning and generalisation (e.g., Olguin & Tomasello, 1993; Tomasello, 2000). Some of the early work on structural priming in children seemed to support the latter position: that children's syntactic knowledge is initially lexically-based (Savage, Lieven, Theakston, & Tomasello, 2003). More recent work from the child priming literature, however, has suggested that these early representations are abstract from relatively early on (e.g., Bencini & Valian,

2008; Rowland, Chang, Ambridge, Pine, & Lieven, 2012). This approach of using structural priming to test what young children know about syntax at the beginning has indeed been a useful way of distinguishing between the core predictions of nativist and constructivist theories of acquisition. However, this focus on the nature of children's initial representations, rather than the process of development, means that it is still unclear how children acquire adult-like syntactic knowledge.

The aim of the current work was to address this issue by looking at how priming changes with age in a paradigm that can be used in the same way with adults and young children. By studying both children's and adults' responses in a series of structural priming tasks, this thesis explores what knowledge children bring to the language learning task, how this knowledge changes over development, as well as how acquisition mechanisms interact with the input to build mature linguistic knowledge. In particular, this work focuses on the role that the verb plays in structural priming to investigate the relationship between syntactic structure and the verb lexicon in children and adults.

The aim of the first chapter is to outline the predictions made by lexical constructivist and early abstraction accounts of syntax acquisition, and to provide an evaluation of these theories with empirical research. This chapter also describes the developmental priming studies that have focused on adjudicating between them.

The aim of chapter two is to review the adult priming literature. This section describes the effects that have been found, and what these effects

can tell us about adults' syntactic representations and how they are linked to the verb lexicon. The chapter ends by discussing the motivation for the thesis: that investigating lexical effects on structural priming in children and adults can tell us about the development of syntactic structure, and the relationship between the verb lexicon and syntactic structure across development.

In chapter three, the aim was to investigate when and how children develop knowledge of verb argument structure for the dative. The chapter reports the results from study 3a: an analysis of the Manchester corpus conducted to identify the syntactic preferences (verb biases) of four familiar alternating dative verbs in child-directed speech; and study 3b: a structural priming study that investigated whether children (as young as 3;0) and adults' knowledge of the biases of these verbs influences their choice of prepositional and double object datives in a priming task (a version of this chapter has been published in the Journal of Memory and Language).

In chapters four and five, we explored, in more detail, some of the adult priming effects in chapter 3, in order to investigate possible explanations of the age-related differences reported in chapter 3. In study 4a, we report on a structural priming study that explored whether modulating the frequency of biased alternating dative verbs affects dative structure choice in adults. The chapter also reports the findings from study 4b: a grammaticality judgement task that investigated whether structural priming is modulated by the perceived grammaticality of prime sentences with low-frequency dative verbs (those sentences used in study 4a).

The aim of chapter five was to use structural priming to explore whether adults are sensitive to prime surprisal with ungrammatical primes containing non-alternating dative verbs. The chapter presents the findings from study 5a, which tested whether adults are primed more strongly by ungrammatical prime sentences than by grammatical prime sentences; and study 5b, which tested whether grammatical prime sentences with non-alternating dative verbs (some of those verbs used in study 5a) influence adults' choice of prepositional and double object datives.

In chapter six, we turned to transitive structures to investigate how children and adults store knowledge about the verb-structure preferences of transitive verbs from different semantic classes. The chapter reports the findings from study 6 which tested whether children's (as young as 5;0) and adults' knowledge of the biases of these verbs influences their choice of active and passive target sentences.

The final chapter concludes by discussing the implications of the findings as a whole for theories of syntactic acquisition and development. It also identifies the direction for future research and discusses the need for a testable theory of syntactic development that considers the pattern of children's item-based and abstract syntactic knowledge across development.

1.2. An introduction to theories of syntax acquisition

In all languages, words are ordered and combined according to grammatical rules. In particular, the construction of sentences in grammars that rely on phrase-structure (such as English) involves the manipulation of categories,

and not individual words (Chomsky, 1957). The fact that children are not explicitly taught the rules that stipulate how these categories are manipulated means that in order to form meaningful utterances, children must have access to, and store knowledge about, a range of abstract, complex, and often seemingly arbitrary syntactic patterns. For example, when learning the rules for the formation of the transitive structure in English, children must learn (amongst other information): a) the grammatical marking of semantic roles such as agent and patient; b) how to map these semantic roles onto syntactic positions (e.g., subject and object); c) that while some verbs can be used transitively, others cannot (e.g., *The boy fought his opponent*/**The boy swam his opponent*), and d) that altering word order can have semantic consequences (e.g., *The girl pushed the boy* means something different from *The boy pushed the girl*). Remarkably, children seem to acquire this knowledge with no formal teaching and, for most, with apparent ease. The question is, how are they able to correctly assign words to the different categories required by their language, and how are they able to combine these categories to produce language that is not only grammatical, but meaningful too?

One school of thought - the early abstraction account, suggests that children's early syntactic representations are abstract, and are acquired at an early stage in development (Chomsky, 1965; Naigles, 1990; Pinker, 1984). On this view, syntax acquisition is driven by early (and for some, innate) knowledge of structure and linking rules (Fisher, 2002; Pinker, 1984). An alternative approach, however, is that children's syntactic representations begin as semi-abstract, item-based patterns that are built around lexical

items heard in the input (Bannard & Matthews, 2011; Childers & Tomasello, 2001; Lieven, Pine, & Baldwin, 1997; Maratsos, 1979; Rubino & Pine, 1998). On this view – the lexical constructivist account, the abstraction of syntactic patterns, through a process of generalisation across sentences, does not to occur until later (Tomasello, 2000). The aim of this chapter is to first, outline the predictions made by lexicalist and early abstraction theories of syntax acquisition, and then, to discuss the priming literature that has attempted to distinguish between these two approaches.

1.2.1. Lexical constructivist approaches to syntax acquisition

Lexical constructivist accounts of syntax acquisition start with the lexical specificity of children's early speech. These theories propose that children's early syntactic representations are limited, at first, to knowledge of the behaviour of individual lexical items, or narrow conceptual/semantic categories (e.g., Goldberg, 1999; Tomasello, 1992). According to these accounts, rather than initially representing syntactic information in an abstract form, as claimed by early abstraction theories, children start out with item-based representations that only link together elements with shared semantic and positional features. Then, through a process of generalisation (using mechanisms like analogy and distributional learning), and through the comparison of patterns that share form (i.e., sentence position) and meaning, there is a gradual emergence of abstract categories (Tomasello, 2003). As a result, children eventually cease to rely on item-based schemas, and employ these abstract categories in order to generalise across utterances (Abbot-Smith, Lieven, & Tomasello, 2001; Matthews, Lieven, Theakston, &

Tomasello, 2005; Pine, Lieven, & Rowland, 1998; Tomasello, 2000). On this approach, the ability to recognise the distributional regularities of the input (through statistical learning and domain-general pattern recognition) is fundamental for the formation of abstract syntactic categories (Cartwright & Brent, 1997; Gerken, Wilson, & Lewis, 2005; Redington, Chater, & Finch, 1998). Thus, not only does the lexical constructivist account predict that children make use of a number of statistical cues (such as item repetition and positional order), but it also suggests that the language to which children are exposed is crucial in the development of syntax (de Marneffe, Grimm, Arnon, Kirby, & Bresnan, 2012; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002).

1.2.1.1. Pivot grammar

For lexical constructivist approaches, therefore, the acquisition of syntactic categories relies heavily on children's ability to extract patterns in the language by paying attention to the distribution of words in sentences. One of the earliest theorists to argue that children are able to perform this type of analysis was Braine (1963). Through observations of children's spontaneous speech, he proposed that many of children's early two-word combinations are characterised by the pairing of an open class word – a low frequency word with a variable position that also occurs alone (e.g., a verb, or an adjective) – with a "pivot word". Pivot words are a small class of high frequency words that: a) always appear in a fixed position (either at the beginning or end of an utterance); b) appear frequently in an utterance; c) do not occur together, and d) do not occur alone. So, for example, a pivot word

could be an adjective like *more* or *gone*, a verb like *want* or *jump*, or a preposition like *off*. From this, Braine put forward his theory of pivot grammar, which posits that the two-word combinations that children produce reflect the order in which they have been heard in the input. So, for example, the theory predicts that a child who has heard language in which the pivot word *more* most frequently appears at the beginning of an utterance, will only produce *more* + *X* combinations like "*more juice*", and not combinations like "*juice more*". Similarly, a child who hears the pivot word *off* produced most often in a final position in an utterance, should only produce *X* + *off* combinations like "*shoe off*", and not "*off shoe*".

While this allows us to predict what children will and will not say, the evidence does not seem to fit the theory: Pivot words do occur in isolation, and children do produce utterances in which one pivot word is combined with another (e.g., *more gone*; Bowerman, 1973). One other problem for this account is that Braine considers children's early knowledge of categories and rules as completely different from the abstract syntactic knowledge held by adults. This misses the fact that children know more about language than just positional word order. For example, Bloom (1970) reported that a child, Kathryn, produced the utterance "*Mummy sock*" on two different occasions in two different contexts: once when picking up a sock that belonged to her mother, and another time when Kathryn's mother was putting a sock on Kathryn. It is likely that on the first occasion, the intended meaning was, "this is Mummy's sock", but that on the second occasion, Kathryn wanted to express the idea that, "Mummy is putting my sock on". This suggests that young children have knowledge about at least two different syntactic rules:

one to express possession and one to indicate causation – a prediction not made by Braine's purely positional theory. Probably, the biggest limitation of the pivot grammar account, however, is that it does not explain how children manage to move on from a formulaic system that only includes two word classes, to an adult-like system in which there are a number of syntactic categories, as well as rules by which these categories are combined. As such, this theory does not provide an account of how syntactic development happens.

1.2.1.2. The verb-island hypothesis

More evidence to account for the lexical specificity of children's early speech comes from work by Tomasello (1992) who collected a detailed corpus of his daughter Travis' early multi-word speech (between the age of 1;0 and 2;0), noting all instances in which these utterances included verbs and other predicates. He found that Travis used semantically-similar verbs in quite different ways from each other. For example, she produced simple utterances with *cut* (e.g., *cut* + *X*), but a wider variety of utterances with *draw* (e.g., *draw* + *X*, *draw X on Y*, and, *draw X for Y*). Tomasello also noted that Travis' performance with each verb tended to start off simply, and get progressively more complex. From these findings, he proposed his verb-island hypothesis - the idea that children initially treat each verb independently as if it had its own island of organisation. On this view, children do not initially establish links between other verbs, but only create links between verbs and the predicate structures to which they are related.

This can explain why Travis's use of *cut* differed from her use of *draw*: she did not have verb general knowledge of argument structure because she had only learned about how *cut* and *draw* behaved on a verb-by-verb basis.

One limitation of corpus data, of course, is that having a record of what a child has said is not the same as having a record of what that child has the knowledge to say. Nevertheless, the results from the experimental data (in particular elicited-production tasks) seem to fit with the observational findings (e.g., Olguin & Tomasello, 1993). For example, in Tomasello and Brooks' (1998) elicited-production study, three-year olds were unable to use novel verbs transitively if these verbs had been taught in an intransitive structure, suggesting that children of this age do not generalise new verbs into an abstract verb category for use in other verb-frames, but instead form lexically-specific schemas based on what they have heard in the input. In other words, as predicted by the verb-island hypothesis, young children do not apply the syntactic rules to all the lexical items to which these rules apply because they do not yet have the verb-general knowledge to do so.

There are, however, some limitations to Tomasello's (1992) theory. For example, other findings have revealed that it is not only verbs that act as islands; Pine, Lieven, and Rowland (1998) showed that children also build item-based schemas around pronouns. To add to this, work by Akhtar (1999) has indicated that two-year olds have more verb-general knowledge than they have been credited with. Findings from her task revealed that, although two-year olds were more willing than four-year olds to use novel verbs in a non-canonical (ungrammatical) word order (e.g., subject-object-verb (SOV); *Elmo the cow tammed),* they were able to correct to the canonical subject-

verb-object (SVO) word order over 50% of the time, suggesting that children of this age are able to generalise their knowledge of agent-patient roles to other verbs. More criticism of Tomasello's interpretation of children's conservatism comes from Fisher (2002) who argues that, as is shown in a number of studies (Naigles, 1990; Fisher, 1996), a child's interpretation of a novel verb will differ according to the context in which that verb is encountered. As such, we should not expect a child who hears a verb in one structure to assume that it can be generalised to others.

1.2.1.3. The usage-based model

The lexically-based nature of children's early syntactic knowledge can also be explained by the usage-based model of language acquisition - a central tenet of which is that syntactic acquisition is achieved by the repeated use of constructions, and is driven by cognitive and social skills (Tomasello, 2000). A key claim of the usage-based model is that language is made up of a number of constructions into which various items can be slotted, and that each of these constructions is associated with a particular meaning. To use language productively, children must learn which items fit appropriately into the slots in various constructions. Fundamental to the usage-based model is that children do not need innate linguistic knowledge to do this; they need only employ the socio-cognitive skills (e.g., pattern-finding and intention-reading) that they use for other types of learning (Goldberg, 1999; Tomasello, 2003).

On this model, a child begins with a small number of lexically-based schemas that have been rote-learned from the input (e.g., *eat dinner*, *eat cake*). Using pattern-finding and intention-reading skills, the child begins to recognise the similarity in meaning across these constructions (i.e., they all involve eating something). This information is stored so that she can produce an "*eat + X*" combination with a number of different *X* items. This knowledge, however, is still tied to the way in which *eat* behaves. To move on from item-based schemas like this, she will need to analogise across the various constructions that she encounters. In doing so, similarities between the "*eat + X*" schema that she has, and the other item-based schemas that she learns will gradually emerge. As such, her knowledge about that construction will become more abstract and thus, more adult-like. A number of studies have found support for the predictions made by this theory. For example, Matthews, Lieven, Theakston, and Tomasello (2005) showed that children aged 2;9 were more likely to adopt a weird word order with low frequency verbs than with high frequency verbs, while older children (aged 3;9) preferred the canonical SVO word order irrespective of the verb's frequency. Similarly, Akhtar's (1999) study revealed that the tendency for children to correct from a weird word order to the canonical SVO order increased with age. Thus, these results support the idea that young children's syntactic representations begin as item-specific schemas and gradually become more abstract as experience with a verb and its argument structure accumulates. One problem for this theory, though, is that the results that support the predictions only really account for the language that children produce, and not the language that they understand. Findings from comprehension studies

have suggested that young children do seem to have abstract knowledge of syntax at an age much earlier than that claimed by usage-based models. In particular, the results from preferential-looking tasks have revealed that children are able to generalise across novel verbs from early on in the acquisition process (by as young as 21 months with the active transitive; e.g., Naigles, 1990; Gernter, Fisher, & Eisengart, 2006). Thus, while usage-based accounts can explain why children do not generally show that they are operating with abstract syntactic knowledge in their language production until they are around 3;5 years old (e.g., Akhtar, 1999; Akhtar & Tomasello, 1997), they cannot explain why they show earlier abstract knowledge in their language comprehension.

1.2.2. Early abstraction approaches to syntax acquisition

In contrast to lexical constructivist accounts, early abstraction theories of syntax acquisition claim that young children are sensitive to the abstract formal properties of the speech that they hear, such that they are able to represent this information at a level that is independent of lexical items from the very beginning of the syntax acquisition process (e.g., Valian, 1986). An argument central to these theories is that the input provides few, if any, constraints for learners trying to determine a referent in a real world scene (Quine, 1960). For this reason, early abstraction theories assume that children are endowed with powerful biases that help them to limit the number of hypotheses about the language that they are learning, with the more traditional of these theories arguing that knowledge of linguistic categories and rules is present from birth.

1.2.2.1. Innate principles and parameters (universal grammar)

One such theory is that of Chomsky (1986) who proposes there to be an innate system of general principles applicable to all of the languages of the world. This system, known as Universal Grammar (UG), includes innate knowledge of categories and constraints, which enables us to generate an infinite number of novel utterances (i.e., a generative syntax). On this view, children have innate knowledge of phrase structure (i.e., knowledge of syntactic categories and the rules by which to combine these categories to form meaningful utterances), innate principles of language (i.e., the knowledge that these rules refer to the phrase structure of sentences not individual words), and innate parameters of language (i.e., parameters that are set according to the language being learnt, and allow us to learn any one of the world's languages)[1]. Unlike lexical constructivist accounts, within the theory there is no initial period in which children will represent language in the form of concrete, item-based schemas because it is assumed that children have abstract syntactic knowledge from the outset. Furthermore, while lexical constructivist theories claim that children employ domain-general cognitive mechanisms in the acquisition of syntactic categories and rules, UG proposes that children make use of innate linguistic mechanisms specifically designed for this purpose.

[1] Chomsky (2004: 105) has since revised his theory of UG, somewhat retreating from the domain-specific stance he held previously; more recently, he has proposed that the system of principles and rules is not specific to language but to "general properties of organic systems". On a similar note, he now posits that UG acts merely to restrict all of the possible grammars, allowing for variation in the constraints and principles across languages (Chomsky, 2005). The original version, however, is still the most influential in the language acquisition literature.

So, why do these theories claim that children need to bring such powerful innate knowledge of linguistic categories and constraints to the language learning task? One argument is that although learners are likely to have been exposed to different speech input, they all end up with a similar grammar. This convergence, Chomsky (1975: 11) argues, "…can be explained only on the assumption that these individuals employ highly restrictive principles that guide the construction of the grammar". Probably the most well-known argument that is used to support UG, however, is that of the poverty of the stimulus. The premise of the argument is that the linguistic input to which children are exposed is not sufficiently rich to allow them to learn the complexities of their language. Since children only ever encounter a small number of the word combinations that are possible, they will simply not be able to explore all of the distributional relations in the input. It is acknowledged that a child will need to employ probabilistic skills to learn the rules that are specific to the language she is learning, but central to the theory is that language acquisition is "…constrained by what appears to be innate and domain-specific principles of linguistic structures, which ensure that learning operates on specific aspects of the input" (Yang, 2004: 455).

The theory of UG is an elegant solution to a complex problem; by co-opting powerful innate linguistic knowledge and mechanisms, UG constrains the potentially infinite number of hypotheses that the child would have to test to achieve adult-like knowledge of grammar. To this end, it can explain why children are able to learn the intricacies of syntactic knowledge despite an impoverished input, as well as why they seem to do this so quickly, and with such ease. However, a significant problem for this theory is that it is difficult

to find reliable, empirical evidence of the innate linguistic knowledge and mechanisms that are proposed. Take, for example, the argument of convergence – the idea that all children share the same grammar despite experiencing different input. This argument is not supported by any empirical research; in fact, recent findings have found evidence inconsistent with this idea (see Street & Dąbrowska, 2010, who found substantial individual differences in what native speakers know about the syntax of their language). The theory also makes no specific predictions about the constraints and biases with which children are equipped (Tomasello, 2004). Furthermore, it makes claims that are unfalsifiable; the theory's assumptions about human languages claim to be universal, but it is not possible to verify this because fewer than 10% of the world's spoken languages have full descriptions of grammar (Evans & Levinson, 2009). These assumptions, therefore, are generalisable only to a small proportion of the world's spoken languages.

In sum, the theory of UG is supported by little empirical evidence, makes claims that are untestable, and serves more as a description of a small sample of the world's spoken languages. As such, it describes only what knowledge children might bring to the language learning process, and not how children might use this innate knowledge to acquire all of the complexities of their language.

1.2.2.2. The semantic bootstrapping hypothesis

In an attempt to address the shortcomings of UG, Pinker (1984) proposed the semantic bootstrapping hypothesis, in which he tackles the fundamental

(but somewhat implausible) assumption of the UG account - that children acquire knowledge about syntactic categories despite there being no evidence in the input to guide this process. His account of verb argument acquisition explains how children use universal innate biases and cross-situational observations of real word events to bootstrap their way into syntax. On this account, there is assumed to be a systematic relationship between thematic roles and syntactic functions to which children are innately sensitive. As such, children learn syntactic categories by making use of a canonical mapping scheme and innate linking rules, allowing them to map certain thematic roles onto certain syntactic positions. Consider the following example:

Example 1

The dog bit the cat

A child who hears the above sentence will initially use context and her knowledge of f-structure (the aspects of semantic structure that may contain syntactic expression) to attempt to identify its meaning. She then uses innate linking rules to map semantic categories onto syntactic categories (e.g., *dog* and *cat* refer to objects and are therefore nouns, *bit* is an action and is therefore a verb, and *the* is a determiner). Since English typically follows SVO word order, when a child hears a transitive sentence like, *"The dog bit the cat"*, contextual information and her innate canonical mapping rules will enable her to extrapolate that English follows this word order. This allows her

to generalise new predicate-argument sequences that also conform to this pattern. Thus, on this account, the acquisition of verb argument structure relies on children initially hearing canonical sentences (i.e., active transitive sentences with agent-patient verbs; *The dog bit the cat*). Once they have successfully learned the rules and built a partial representation for these types of sentences, they will be able to map thematic roles onto syntactic functions for predicate-argument sequences that do not fit with this schema (e.g., passive transitive sentences with theme-experiencer verbs; *The boy is being frightened by the clown*), or in which the contextual information is not rich enough (e.g., active transitive sentences with abstract nouns and non-physical verbs; *The situation justified the measures*, Pinker, 1984).

The semantic bootstrapping hypothesis is a logical nativist attempt to explain how a child would feasibly link her innate knowledge of UG to the language that she hears. However, it assumes that children only initially hear sentences with canonical semantic-syntactic correspondences. Braine (1988) points out that, actually, children do sometimes hear language in which there are ambiguous mappings between verbs and the real world. For example, action words are often used as nouns (e.g., *Did you have a nice sleep?/Shall we go for a walk?*). If, as the theory claims, children learn syntax after parsing a sentence only once, then they would end up with an inaccurate grammar should they wrongly interpret these types of sentences. Whilst, in theory, the semantic bootstrapping hypothesis works well to explain the bootstrapping problem, in reality, it assumes a great deal of innate linguist knowledge (the origins of which are not clear), and it is unlikely

that the language that children actually hear will allow them to use semantics to learn about syntax.

1.2.2.3. The syntactic bootstrapping hypothesis

Pinker's (1984) semantic bootstrapping theory (and indeed those of other nativists such as Valian, 1986) proposes that we build into the syntax acquisition mechanism a huge amount of linguistic knowledge; knowledge of semantic categories, syntactic categories, linking rules, phrase structure rules, and movement rules (see Pinker, 1984; Valian, 1986, for examples). There are, however, early abstraction theories, that do not assume quite this level of innate linguistic knowledge. One example of this is the syntactic bootstrapping account (e.g., Fisher, 2002) which proposes that children use both the syntactic structure of sentences and structure-mapping rules to guide their learning of new verbs and other argument-taking predicates (e.g., Fisher, 1996, 2002; Fisher, Hall, Rakowitz, & Gleitman, 1994; Landau & Gleitman, 1985; Lidz, Gleitman, & Gleitman, 2003; Naigles, 1990). The existence of structure-mapping rules is necessary for this theory because learning verbs simply by associating them with events in the real world is considered too difficult a task. This is because some verbs are argued to be associated with concepts that are too far removed from what might be perceived from observing it in real life (Gilette, Gleitman, Gleitman, & Lederer, 1999). Similar to lexical constructivist accounts, the ability to extract distributional regularities from the environment is considered necessary for verb learning, but, on the syntactic bootstrapping account, these mechanisms alone are not sufficient to drive syntax acquisition (Fisher &

Gleitman, 2002). Thus, a key assumption is that once children are able to identify nouns, they will make use of unlearned structure-mapping rules that bias them to assign each participant in an event to a different thematic argument (Fisher, Gertner, Scott, & Yuan, 2010; Gernter & Fisher, 2012). Given the systematic relationship between the semantic argument-taking properties of verbs (Fisher, Gleitman, & Glietman, 1991), children should expect each term in a sentence to be a semantic argument of a predicate term (Fisher, Klinger, & Song, 2006). Thus, in contrast to lexical constructivist accounts, children do not analogise across an inventory of item-based schemas to generalise their knowledge of semantic categories (like agent and patient) to new predicate-argument structures. By having these unlearned rules, the theory predicts that children will be able to distinguish, for instance, between transitive verbs (where the predicate takes two noun phrase arguments), and intransitive verbs (where the predicate takes only one noun phrase argument). Furthermore, because these biases are present from early on, the acquisition of abstract categories is argued to happen quickly and early in development. This is not the case for lexical constructivist theories in which the emergence of semantic categories via abstraction across item-based schemas is predicted to be slow and gradual.

Findings from preferential-looking studies have been instrumental in supporting claims that children exploit syntactic cues (e.g., the number of nouns in a sentence) to learn the meaning of new verbs. One example of this comes from Naigles' (1990) preferential-looking task in which children (mean age 2;1) watched two screens each showing a novel event. One screen depicted a causative action (e.g., *Look! The bunny is gorping the duck*) and

the other depicted a non-causative action (e.g., *Look! The bunny and the duck are gorping*). Preferential-looking tasks are designed for use with children who are too young to reliably produce certain sentence types, and require that they look at one of two video screens whilst simultaneously hearing a sentence describing an event depicted on one of the screens. It is presumed that children indicate comprehension of the sentence by looking more often or longer at the screen that matches the sentence. In Naigles' task, children looked longer at the scene depicting the non-causal action when they heard the novel verb in the intransitive, and longer at the causal action when they heard the novel verb in the transitive. Since the children had no prior experience with these verbs, this was interpreted as evidence that children as young as two use innate knowledge of semantic relations, like agent and patient, to extrapolate the meaning of novel sentences. Other work has demonstrated similar findings (e.g., Gertner, Fisher, & Eisengart, 2006), and has revealed that the structure-mapping bias predicted by the account is powerful enough to narrow down the possibilities of a verb's meaning even when the utterance is heard in the absence of its associated event. For instance, in Yuan and Fisher's (2006) task, 28-month old children heard novel verbs used transitively (e.g., *Jane blicked the baby*) and intransitively (e.g., *Jane blicked*), in a dialogue between two women. Later on, the children were told to *"Find blicking!"* in a video depicting that event. Children who had heard the novel verb used transitively, looked reliably longer at the event with two participants, and the children who had heard the novel verb used intransitively looked longer at the event with one participant. Thus, even though children had only heard the utterance, but not seen the

associated event, they were still able to use the number of nouns as a scaffold for their interpretation of these novel sentences.

Supported by empirical findings, the syntactic bootstrapping hypothesis provides a straightforward explanation of how children are able to exploit syntactic cues to guide their sentence interpretation with new verbs. The account, however, does not offer a perfectly convincing story about the acquisition of syntax. For instance, one criticism of this approach is that if, as predicted, children use syntactic cues to learn new verbs, they must have some knowledge of syntax from very early in the acquisition process. Yet, research has revealed that not only do children fail to generalise their knowledge of SVO word order to other verbs (Tomasello, 1992), but they are not always able to use syntax as a guide for understanding sentences with novel verbs (Fisher, 1996). Goldberg (2004) raises a further problem for the account: the surface structure available to children does not always complement what is semantically expressed; there are many situations in which the number of noun phrases that are expressed does not match the number of semantic participants that are conceptualised in the scene. For example, in the sentence *"Pat buttered the toast"*, two noun phrases are expressed linguistically: *Pat* and *the toast*. However, there are actually three semantic participants involved: *Pat*, *the toast*, and *the butter* (being spread on the toast). So, in cases like this one, children cannot use the number of noun phrases to bootstrap into syntax. Finally, the syntactic bootstrapping account does not make clear how children's early partial sentence representations develop into phrase structure grammar. As such, the question of how children move on from their early abstract knowledge of

thematic roles to an adult-like understanding of syntactic roles remains unanswered.

1.3. Problems with lexical constructivist and early abstraction accounts as theories of syntactic development

In sum, there is compelling evidence to support both approaches to syntax acquisition but, currently, neither approach can fully explain the pattern of children's early syntactic knowledge. Early abstraction accounts like the theory of universal grammar, have problems explaining why children's early speech is not adult-like; if children have innate knowledge of linguistic parameters and principles that help them to constrain the possible hypotheses about the language that they are hearing, why do they make overgeneralisation errors in their early speech? In addition, if children have such powerful innate linguistic knowledge that affords them the potential to produce an infinite number of novel utterances, why is it that a large proportion of their early multi-word utterances are explained by a relatively small number of lexically-based schemas (Lieven, Pine, & Baldwin, 1997)? In other words, unlike lexical constructivist accounts, which predict a close relationship between the lexicon and syntactic structure, early abstraction accounts have problems explaining the lexical specificity of children's early speech. That is not to say that lexical constructivist accounts are without their issues. Although accounts like the usage-based theory can explain why children's early speech tends to be built around highly frequent item-based fragments, they, like nativist accounts, struggle to explain how children are able to constrain their speech so that do not end up with an over-general

grammar. These accounts also have difficulty explaining why children show evidence of abstract knowledge in their language comprehension (i.e., why they are able to understand sentences with novel verbs from early in the acquisition process) (e.g., Naigles, 1990; Gertner, Fisher, & Eisengart, 2006).

To add to this, both elicited-production and preferential-looking tasks - the traditionally-preferred paradigms used to test the abstractness of children's syntactic representations, may contain methodological flaws that make it difficult to draw firm conclusions about the way in which children represent syntax. First, both types of paradigm use novel verbs. This is because the use of novel verbs allows a high degree of control over the language to which the children are exposed, ensuring that the speech produced or comprehended is creative and does not occur as a result of previous experience. The problem with this is that, as argued by Fisher (2002), using novel verbs in production tasks also introduces the possibility that young children will have difficulty producing these new verbs after only a few experimental sessions; the increased cognitive load (as a result of the additional memory demands when learning new verbs) during elicited-production tasks might make it difficult for children to access the appropriate syntactic representations (Valian, Solt, & Stewart, 2009). Another disadvantage of using novel verbs is that it is not always clear that children will have learned the verb's meaning. For example, while the use of preferential-looking tasks has many advantages (e.g., enabling researchers to test children at a much earlier stage of the acquisition process than elicited production tasks will allow), these tasks may not directly test whether

children understand the meaning of verbs that they have never encountered before. They may instead test whether or not children can tell the difference between a pair of sentences – which, arguably, might not rely on abstract syntactic knowledge. For example, in Naigles' (1990) task, it may simply be that for intransitive sentences, children associated the word '*and'* with the absence of causation, in which case, knowledge of abstract syntax might not be necessary in determining that "*The bunny and the duck are gorping"* is a non-causal event. Another problem with these types of tasks is that the time spent looking at the screens is not a fail-safe measure of whether or not children understand the sentences that they are hearing. For instance, in Gertner et al.'s (2006) study, children may have just looked longer at the correct screen because they preferred to look at the first-mentioned character who, as the agent, is always the protagonist. Alternatively, children may look longer at the incorrect screen because they find the discrepancy between the video and the sentence more interesting (Ambridge & Rowland, 2013). Thus, while these studies might claim that young children are able to use syntactic knowledge to understand novel sentences, they do not provide conclusive evidence that this knowledge is sophisticated enough to enable them to generalise across a range of sentence types. Further still, in production tasks, children are exposed to each novel verb many times during training sessions. Effectively, the novel verbs are primed in one structure before the child is encouraged to use it in another, making it potentially more difficult for the child to use the novel verbs in a different way.

An alternative way of adjudicating between lexical constructivist and early abstraction accounts is to use structural priming since this paradigm

uses familiar verbs and tests for the effects of priming directly. Not only does the structural priming paradigm obviate the need for novel stimuli by using familiar verbs, but the degree of overlap in lexical content between prime and target sentences can be controlled, allowing for the investigation of different levels of abstractness in children's early syntactic representations. The next section reviews the developmental priming literature. First, we explain how the structural priming paradigm works. Then, we describe the effects that have been found, and discuss what these effects can tell us about children's early syntactic representations.

1.4. A review of the developmental priming literature

Speakers tend to re-use the syntactic structure of the sentences that they have recently encountered. This effect is known as *structural priming* (e.g., Bock, 1986). In production priming tasks, participants are usually presented with sentences that use a particular structural form (a prime), and it is then observed whether they re-use this structure (rather than an alternative one) when producing a new sentence (a target). Comprehension priming tasks are slightly different: Participants are tested to see whether the structure of the prime to which they have previously been exposed facilitates their processing of subsequent syntactically-similar sentences. Both production and comprehension studies tend to use sentences containing dative or transitive verbs. This is because these types of verb can often alternate between structures that are semantically-similar but are syntactically-different. For example, a dative verb like *give* can alternate between the double object dative (DOD) and the prepositional object dative (PD), and a

transitive verb like *hit* can alternate between the active and the passive. This means that by observing, for instance, whether participants are more likely to produce a DOD target after a DOD prime (compared to after a PD prime), researchers can conclude that this effect has occurred as a result of similarities in structure across sentences, and not similarities in meaning. Consider the following example:

Example 2

(a) DOD prime: *A journalist sent the editor an article*

(b) DOD target: *The boy threw the girl a ball*

(c) PD target: *The boy threw a ball to the girl*

After hearing 2(a), participants are more likely to produce 2(b) than they are to produce 2(c), even though sentences 2(b) and 2(c) are essentially equivalent in meaning. As there is no similarity in lexical content and little similarity in meaning across 2(a) and 2(b) (aside from the act of object transfer), repetition of the prime's structure indicates that participants are primed by the syntax of the sentence. In other words, this effect is structural. As a result, effects of structural priming are widely interpreted as evidence that syntax is represented abstractly and that these representations are used to generalise across similarly-structured sentence types. Thus, the key reason that structural priming has been researched so extensively is that it can be used to test theories of how we process and represent syntactic information.

Over the past few decades, the findings from structural priming studies in adults have provided insight into the nature of adult syntactic representations, and have been instrumental in shaping theories of sentence processing. More recently though, researchers have used structural priming to look at how children represent syntactic structure early in the language learning process. So far, the child studies have focussed on trying to distinguish between early abstraction and lexical constructivist accounts of acquisition by investigating, a) whether children show evidence of abstract structural priming from a young age, thus supporting early abstraction accounts of acquisition, or b) whether priming effects in children are initially lexically-dependent (i.e., priming is observed only when there is lexical overlap between primes and targets), thus supporting lexical constructivist accounts of acquisition.

An early study by Savage, Lieven, Theakston, and Tomasello (2003) supported the lexical constructivist approach. Three, four-, and six-year olds heard active and passive prime sentences, before describing animations of causative events. The amount of lexical overlap across prime and target sentences was manipulated so that half of the children heard primes that had high lexical overlap with targets (i.e., pronouns/grammatical morphemes in the prime could be used in the production of the target), while the other half heard primes with low lexical overlap. Interestingly, the three- and four-year olds were only primed when there was high lexical overlap. In other words, they showed no evidence of abstract structural priming. The six-year olds, on the other hand, showed evidence of priming in both conditions. These findings fit with theories in which early syntactic knowledge is lexically-based,

but becomes more abstract with development (e.g., Matthews, Lieven, Theakston, & Tomasello, 2005; Pine et al. 1998; Tomasello, 2000). However, it is worth noting that the absence of abstract priming in the youngest children could be an artefact of the task's design. For example, the prime sentences in this study had unusual structures not typical in everyday speech (e.g., in the high lexical overlap condition the agent and patient were described using the same pronoun; ***It*** *is pushing* ***it***). This kind of repetition may have made these primes more salient for the youngest children, which could explain why priming for this group was only found in the high overlap condition. In addition, the number of trials in the task is considerably smaller than in subsequent studies that have found robust structural priming in children as young as three (e.g., five trials in Savage et al. vs. 12 trials in Rowland et al., 2012). It may be that the inclusion of only five trials was not enough to detect a significant abstract priming effect in the youngest children.

Shimpi, Gámez, Huttenlocher, and Vasilyeva (2007), however, reported very different results. In their production task, three- and four-year olds heard blocks of ten prime sentences (dative and transitive), before describing blocks of target pictures. Structural priming was found for the four-year olds, but not for the three-year olds. However, when the task was altered so that the children repeated each prime sentence before immediately describing the target pictures, both three- and four-year olds showed evidence of structural priming. Thus, it may be that the use of a more constrained procedure increased the salience of the prime's structure. This clearly demonstrates that the format of the task is integral to the

detection of priming effects in young children. It also serves as a reminder that failure to find evidence of abstract structural priming in young children does not always reflect absence of syntactic knowledge, but might instead be attributable to task demands.

Most of the production studies since then have indicated that children have acquired at least some abstract syntactic representations that enable them to generalize across similarly-structured sentences by about the age of three. For example, in Bencini and Valian's (2008) study, three-year olds who were primed with passives (e.g., *The chair is covered by the blanket*) were more likely to produce passive sentences (e.g., *The car is lifted by the truck*) compared to those primed with actives and those not primed at all. More recently, Messenger, Branigan, McLean, and Sorace (2012) tested whether three-year olds would show abstract structural priming with active and passive primes containing agent-patient (AP; *hit*) and theme-experiencer (TE; *frighten*) verbs. They found that three-year olds produced 28% and 24% more active responses after active primes than after passive primes with AP verbs and TE verbs, respectively. Interestingly, the priming effect was even stronger for passive primes; children produced 58% and 45% more passive responses after passive primes than after active primes with AP verbs and TE verbs, respectively. As prime and target sentences did not share a verb, the findings indicate that from as young as three, children have formed an abstract representation of both the passive and the active that allows them to generalise across other similarly-structure sentences.

Abstract structural priming effects have also been demonstrated in comprehension in three- and four-year olds. In Thothathiri and Snedeker's

(2008a) task, three- and four-year olds acted out DOD and PD sentences (e.g., *Give the lion the ball/Give the ball to the lion*) while their eye-movements were tracked. The authors found that children's interpretation of target dative sentences was influenced by prior processing of dative prime sentences that contained a different verb (see their Experiment 2b), suggesting that children as young as three possess verb-general representations that they employ during comprehension.

In short, the findings from the child priming studies provide compelling support for early abstraction accounts of syntax acquisition; in both production and comprehension, children show that they have abstract knowledge of syntactic structure that: a) allows them to generalise across other similarly-structured sentences, and b) is independent of lexical items. The next chapter reviews the findings from the comparatively broader adult priming literature. We also discuss the need for a single priming task that can assess structural priming in children and adults, before explaining why investigating the lexical effects on children's and adults' structure choice can inform us about verb-structure links across development.

Chapter 2

A review of the adult priming literature

Chapter 2: A review of the adult priming literature

2.1. Outline

This chapter begins with a review of the adult priming literature. First, we describe the various effects that have been found, and then discuss what these effects tell us about adults' syntactic representations and how they are linked to the verb lexicon. We then discuss the need for a priming task that can assess structural priming over development, before explaining why investigating lexical effects on children's and adults' structure choice can inform us about the development of syntax and of verb-structure links.

2.2. The adult priming literature

2.2.1. Priming in production

One of the earliest studies to report evidence of structural priming in adults was a production study by Bock (1986). In the task, adults heard and produced dative and transitive prime sentences describing a series of pictures. Dative primes were presented in either the double object dative (DOD) (1a) or the prepositional object dative (PD) (1b) structure, and transitive sentences were presented in either the active (1c) or the passive (1d).

Example 1

(a) The man is reading the boy a story

(b) The man is reading a story to the boy

(c) Lightning is striking the church

(d) The church is being struck by lightning

After producing each dative prime, adults described a semantically-unrelated target picture that could be described using either a DOD or PD, and after a transitive prime, they described a picture that could be described using either an active or a passive. Bock found that adults produced 23% more PD targets after PD primes than after DOD primes, and 22% more DOD targets after DOD primes. They were also 8% more likely to produce active descriptions after active primes and produced 8% more passive descriptions after passive primes. In other words, adults tended to echo the syntax of the prime sentence even though they could have produced a target sentence to convey the same meaning using the alternative syntactic structure. Remarkably, this repetition of the prime structure was found not to be deliberate; post-experimental questions revealed that adults: a) did not believe there to be a relationship between the sentences and the pictures; b) did not feel that their target descriptions had been influenced by the sentences that they had heard; and c) believed that the task merely involved recognition of sentences and pictures.

One possibility, of course, is that the adults were primed by the repetition of the closed-class and function words in the prime sentences (i.e., *to*, *for, by*). However, given that participants were primed by active and DOD

sentences (which do not contain closed-class markers), and since the amount of priming with prepositional-*to* sentences was not significantly different from the amount of priming with prepositional-*for* sentences, it does seems likely that priming is not sensitive to function words and instead relies on the abstraction of syntactic structure across sentences. In fact, later work provided further support for the idea that structural priming depends on abstract structural similarities across sentences, and not on superficial comparisons between lexical items: Bock (1989) found that adults were just as likely to produce prepositional-*to* targets after prepositional-*to* primes as they were after prepositional-*for* primes. So, for example, the sentences *A secretary is taking a cake to her boss* and *A secretary is baking a cake for her boss* were equally likely to prime adults to produce *The girl is handing a paintbrush to the man*.

Another possibility, however, is that priming reflects speakers' tendency to copy thematic roles, rather than the phrase structure itself. To test this, Bock and Loebell (1990) investigated whether adults were primed by conceptual similarities across sentences (as defined by event roles). Consider the following example taken from their study:

<u>Example 2</u>

(a) PD-prime: *IBM promised a bigger computer to the Sears store*
[AGENT] [VERB] [THEME] [BENEFICIARY]

(b) Prep-loc prime: *IBM moved a bigger computer to the Sears store*
[AGENT] [VERB] [THEME] [LOCATION]

(c) DOD-prime: *IBM offered the Sears store a bigger computer*
[AGENT] [VERB] [BENEFICIARY] [THEME]

If participants are primed by conceptual features, then they should be more likely to produce PD target descriptions after prime sentences like 2(a) (a PD) and 2(c) (a DOD). This is because 2(a) and 2(c) describe similar conceptual events, with both including an agent, a theme, and a beneficiary. If, however, participants are primed by the structure of the prime sentence, and not by conceptual features, then they should be more likely to produce PD target descriptions after a prime sentence like 3(b) (a prepositional-locative). This is because although 2(b), describes an event that is conceptually different from that that would be described by a PD target, prepositional-locatives are structurally similar to prepositional-object datives (both include a subject, direct object, and an oblique object in a prepositional phrase). Bock and Loebell found that adults were just as likely to produce PD targets after prepositional-locative primes as they were after PD primes, suggesting that adults' structure choice was influenced by the syntactic structure of the prime sentences and not by overlap in the thematic roles across sentences. Still, the authors noted that since beneficiaries and locations are alike (in that they are both classified as goal arguments), adults may have been primed simply because they viewed these thematic relations as conceptually-related. So, in their second experiment participants were primed with sentences in which the event roles of the noun-phrases were more contrasting: passive-*by* prime sentences and prepositional locative primes with a *by* phrase. As an example, consider the following prime sentences used in their study:

Example 3

(a) Passive-*by*: prime	*The construction worker*	*was hit*	*by the bulldozer*
	[PATIENT]	[VERB]	[AGENT]
(b) Prep-loc prime:	*The construction worker was digging*		*by the bulldozer*
	[AGENT]	[VERB]	[LOCATION]

While 3(a) and 3(b) are syntactically alike, they are thematically different. This is because in passive-*by* sentences the object is the agent, but in prepositional-locative sentences with a *by*-phrase, the object is the location. All adults in Bock and Loebell's task heard and produced passive-*by* primes and prepositional-locative primes with a *by*-phrase before describing pictures designed to elicit either an active or a passive target response. If priming is truly structural, and adults are not influenced by thematic relations across sentences, then they should be just as likely to produce passive target descriptions after prepositional-locative primes as they should after passive-*by* primes. This is exactly what Bock and Loebell found. Furthermore, they showed that priming was not influenced by prosodic (rhythmic) similarities across prime and target sentences. In their final experiment, they found that adults were more likely to produce a PD target description such as *The girl gave a brush to the man* after a PD prime like *Susan brought a book to Stella,* than after a prosodically-similar but syntactically-different prime like *Susan brought a book to study.* So, even though both primes share the same number of syllables and lexical stress patterns, adults were more likely to repeat the prime's syntactic structure, rather than its prosodic pattern. Taken together, the findings provide convincing evidence that priming is structural in

nature, and that adult speakers are not simply primed by thematic relations or the rhythmic shape of sentences.

Since then, the findings from structural priming tasks have been consistent, with robust effects being found in adults in spoken as well as written production (e.g., Branigan, Pickering, & Cleland, 1999; Pickering & Branigan, 1998). As such, researchers have argued that adults have highly abstract knowledge of syntactic structure. Moreover, because priming effects are found even when prime and target sentences share no words, this knowledge is also argued to be independent of lexical items.

Nevertheless, the repetition of verbs across sentences has been shown to increase the size of the priming effect – an effect referred to by Pickering and Branigan (1998) as a *lexical boost*. In their study, adults completed prime sentence fragments designed to favour either a DOD (e.g., *The mother gave the hungry baby...*) or a PD structure (e.g., *The mother gave the expensive toy…*), before completing target fragments containing either the same or a different verb, but with no cues to favour either structure (e.g., *The air hostess gave…*). Adults were more likely to produce PD target completions following completion of PD primes, and DOD target completions following DOD primes. Interestingly, this priming effect was larger when the prime and target shared a verb (17.2% more target completions matched the structure of the prime completion when the verb in the prime and target was the same compared to just 4.4% when verbs in the prime and target were different). Other studies have found similar results when verbs are repeated across sentences. For example, Branigan, Pickering, and Cleland (2000) reported a lexical boost of 29% in their spoken dialogue task; priming was

stronger when the prime and target verb were the same (55%) compared to when they were different (26%), and Hartsuiker, Bernolet, Schoonbaert, Speybroeck, and Vanderelst (2008) found evidence of a lexical boost, this time in written dialogue. In their task, adults were 28% more likely to produce the same syntactic structure as in a prime sentence when the prime and target verb were different, but 45% more likely to re-use the prime's structure when prime and target shared a verb. Findings like these suggest that although adults have abstract representations of syntactic structure, they also store links between these representations and verbs.

2.2.2. Priming in comprehension

In comparison to the results from production priming studies (which have proved robust and replicable), the findings from comprehension studies are less conclusive. In particular, the design of some of the earlier comprehension studies makes it difficult to draw firm conclusions about the effects observed.

One example of this comes from a comprehension study by Mehler and Carey (1967). In this task, adults heard a block of ten syntactically-similar sentences that were obscured by white noise (e.g., *They are forecasting cyclones).* After each sentence, adults were instructed to write down what they thought they had heard before the next sentence was played. They then heard an eleventh sentence which shared the preceding sentences' surface structure, but was actually different in syntactic structure (e.g., *They are recurring mistakes*). The authors found that adults were better at interpreting the first ten sentences (which all had the same syntactic

structure) than the eleventh sentence which had a different syntactic form. In other words, sentence comprehension was facilitated if the preceding sentence also shared that syntactic structure, but was disrupted if the syntactic structure of the preceding sentence was different. It should be noted, however, that the presentation of prime sentences in a blocked format introduces the possibility that adults might be able to explicitly identify similarities between primes and targets. An alternative explanation, therefore, could be that priming in their task occurred as a result of explicit strategic processing.

Another example comes from Noppeney and Price (2004) who also used a blocked design. While adults silently read blocks of either syntactically-similar or syntactically-different sentences, both their reading time and blood-oxygenation level dependent (BOLD) response was recorded. The BOLD response is measured using fMRI and reflects neural activity. When consecutive sentences had the same syntactic structure, adults' reading time and neural activity in the anterior temporal region of the brain was reduced. This suggests that processing sentences with a particular syntactic structure facilitates the processing of subsequent sentences with that same structure. However, since primes were presented in a blocked format, again it is possible that adults were conscious of the similarities between primes and targets. Thus, while the findings have been interpreted as evidence for abstract structural priming in comprehension, we cannot be sure that abstract knowledge of syntax, and not explicit strategies or techniques were used to facilitate the processing of similarly structured sentences.

To add to this, many of the comprehension studies have only found priming effects when verbs are repeated across sentences. For example, in Branigan, Pickering, and McLean's (2005) task, adults were presented with structurally ambiguous primes (containing a prepositional phrase with an ambiguous attachment) such as *The teacher poking the soldier with the banana*. In this example, the prepositional phrase (i.e., *with the banana*) can form a high-attachment, meaning that the teacher used the banana to poke the soldier, or a low-attachment, meaning that the teacher poked the soldier who was in possession of a banana. After reading each ambiguous prime, adults matched the prime to one of two pictures. One picture corresponded to either the high or the low attachment prime, and one matched neither. They were then presented with a target expression that was syntactically-similar before matching the target expression to one of two pictures (this time, each matched an interpretation of the target). Branigan et al. found that after reading a prime with a high-attachment interpretation, adults were then more likely to interpret a target sentence with an ambiguous prepositional phrase with a high attachment. In other words, they tended to interpret the target sentence in the same way as they had interpreted the prime sentence. However, this effect was only observed when prime and target sentences shared the same verb. This result is not an isolated one: other studies have suggested that lexical repetition is important for priming in comprehension, reporting priming effects only when verbs are repeated across prime and target sentences (e.g., Arai, van Gompel, & Scheepers, 2007, Pickering & Traxler, 2004; Traxler, Tooley, & Pickering, 2014).

Some studies, though, have reported priming effects in comprehension that are not dependent on verb overlap. In Thothathiri and Snedeker's (2008b) eye-tracking task, adults heard two non-dative filler sentences followed by either two DOD prime sentences (e.g., *Feed the zebra the candy*) or two PD primes (e.g., *Send the gift to the frog*). They then heard, and were subsequently required to act out, either DOD or PD target sentences containing a temporary ambiguity. Consider the following example taken from their study:

Example 4

(a) DOD-target: *Show the horse the book*

(b) PD-target: *Show the horn to the dog*

Although the direct object nouns in both 4(a) and 4(b) are different, the onset of these nouns is the same (hor-). As a result, both nouns in each of these sentences are initially compatible with either an animate recipient (e.g., a horse) or an inanimate theme (e.g, a horn), creating a temporary ambiguity. It was found that adults who heard DOD primes looked more at the potential recipient (the animal), while those who heard PD primes looked more at the potential theme (the object) at the onset of the noun (hor-). Given that prime and target sentences used different verbs, these results (at least) suggest that adults do make use of abstract lexically-independent representations during language processing. These results are now being backed up by more recent work that has also found evidence of structural priming in comprehension without lexical overlap (see Pickering, McLean, & Branigan,

2013; Kim, Carbary, & Tananhaus, 2014; Tooley & Bock, 2014). Thus, we are beginning to gather evidence that abstract structural priming effects are present in comprehension as well as production.

2.2.3. Priming across languages

Structural priming effects in adults are also not limited to the English language: findings have been reported in bilinguals as well as across a range of languages. For example, priming effects have been shown in native speakers of Mandarin (Cai, Pickering, & Branigan, 2012); Dutch (Hartsuiker, Bernolet, Schoonbaaert, Speybroeck, & Vanderelst, 2008); and German (Scheepers, 2003), and in Korean (Shin & Christianson, 2009) and Spanish bilinguals (Hartsuiker, Pickering, & Veltkamp, 2004). These findings have provided insight into the way in which syntactic information in languages other than English is represented, as well as how this information is represented in bilinguals.

Some work, for example, has shown that the representational systems of languages that use similar syntactic structures are closely linked. One such study is that of Kantola and van Gompel (2011). In their study, native Swedish (L1) adult speakers who were highly proficient in English (L2) completed written DOD- and PD-biased prime fragments (e.g., *The dishonest car salesman offered the elderly lady a.../The dishonest car salesman offered a Volvo to a…*) before completing ambiguous target fragments (e.g., *The busy doctor sent*...). Prime fragments were either in Swedish or English, with target fragments in English in Experiment 1, and Swedish in Experiment 2. The size of the priming effect when the language

of the prime and target sentences matched (English prime-English target/ Swedish prime-Swedish target) was the same as when the language of the prime and target sentences did not match (English prime-Swedish target/ Swedish prime-English target). Furthermore, the priming effects found when English primes were paired with English targets were the same size as the effects found when Swedish primes were paired with Swedish targets. In other words, priming occurred both across (from L1 to L2, and L2 to L1) and within (L1 to L1, and L2 to L2) languages. Semantic priming from L2 to L1 has been shown to be weaker than semantic priming from L1 to L2 (e.g., Duyck, 2005; Fox, 1996), which has been interpreted as evidence that semantic representations are weaker in a speaker's non-native language. One might, therefore, predict a similar pattern for structural priming effects. However, since Kantola and van Gompel found structural priming of equivalent magnitude in both speakers' L1 and L2 languages, this indicates that, for some bilingual speakers, syntactic representations are as strong in their native language as they are in their non-native language. Further still, the fact that similar-sized priming effects were found across and within both languages suggests that the representational systems for Swedish and English are linked closely enough that they can influence adults' structure choice to the same extent in both languages.

2.3. Error-based learning as a mechanism for structural priming

There are a number of theories that attempt to explain the processes that drive structural priming. For example, one idea is that the mechanism that underlies structural priming in children is the same as the one that underlies

analogical reasoning (Goldwater, Tomlinson, Echols, & Love, 2011). Another view is that priming is driven by a domain-general mechanism so that the abstraction of structural representations is not limited to linguistic representations. On this view, it is the overall shape of the representation that is primed, and thus the mechanism that enables abstraction of a linguistic structure is the same one that enables abstraction of a mathematical one (Scheepers, Sturt, Martin, Myachykov, Teevan, & Viskupova, 2011).

A theory that has received attention recently, however, is that structural priming is the consequence of (implicit) error-based learning. This idea has been conceptualised in Chang, Dell, and Bock's (2006) frequency-based connectionist model of syntactic development - the *Dual-path model.* The model has a dual-pathway architecture made up of a simple recurrent network (SRN) and a (hidden) meaning network. The meaning network contains the intended message of the sentence and is important in this model because one sentence may differ structurally from another but may still convey a similar message. For example, the act of object transfer can be expressed by either a double-object dative (DOD; *The boy handed his mum the note*) or a prepositional object dative (PD; *The boy handed the note to his mum*). Syntax learning occurs because the syntax system in the model generates a prediction about the next word in a sentence based on sequential restraints (i.e., the previous word) and information from the meaning network about the type of message that is being conveyed (i.e., the context). It then calculates the difference (or error) between the predicted word and the actual word and uses this prediction error to make gradual

changes in the weights that support syntactic knowledge in the system. Increasing experience and continual feedback strengthen the model's predictive abilities so that, over time, it is able to make more accurate predictions about the next word in a sentence. This type of distributional learning enables the model to gradually develop abstract syntactic categories. Then, using meaning, it is able to sequence these abstract categories to generate sentences. Thus, the small weight changes in the model eventually converge on the representations that support adult-like sentence production. This not only allows the model to learn syntactic structure, but also enables it to develop lexical-structural representations such as verb argument structure preferences (verb bias).

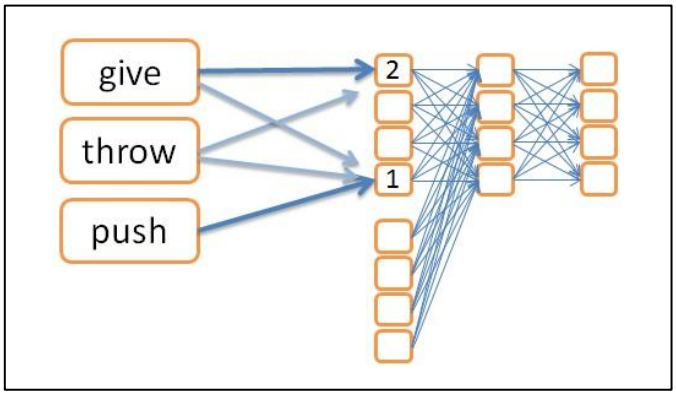

Figure 2.1 *Simplified Dual-path model: the acquisition of verb bias (taken from Chang et al., 2012)*

Figure 2.1 is an example of how verb bias acquisition is conceptualised in the Dual-path model. The SRN in the model that tracks which verbs and structures tend to co-occur is the same mechanism that enables the model to learn verb-structure regularities. In Figure 2.1 below, the three verbs *push*, *throw,* and *give* are linked to the node that signifies a PD structure (node 1: NP-PP). The verbs *throw* and *give* are, however, also linked to the node that

signifies a DOD structure (node 2: NP-NP). Because the model's experience with *give* is that it tends to occur more often in a DOD structure, the link between the *give* node and node 2 is stronger than the link between the *give* node and node 1 (denoted by a thicker blue line in Figure 2.1). This creates a bias for the DOD structure for this verb. Similarly, because the model is presented with *push* more frequently in a PD structure, the link between the *push* node and node 1 is stronger than the link between the *push* node and node 2 (again, denoted by a thicker blue line). This creates a bias for the PD structure for this verb.

Other work has also shown that verb biases are learned in this way: Twomey, Chang, and Ambridge (2014) presented a version of the Dual-path model that gradually learned locative verb biases over development, and Twomey, Chang, and Ambridge (2015) showed that both children and adults used lexical distribution to learn verb classes for novel locative verbs after as little as two exposures. Thus, the Dual-path model provides an account in which syntax acquisition and verb bias acquisition is the result of a common verb-structure mechanism: error-based learning.

Abstract structural priming effects are also caused by this very same error-based learning mechanism. To understand how structural priming effects can be simulated in the Dual-path model, let us consider the following example taken from Chang, Janciauskas, and Fitz (2012) in which the model is presented with a prime sentence that uses a DOD structure: *John threw the man a ball*. The model is tested for priming by presenting the prime sentence with error-based learning left ON.

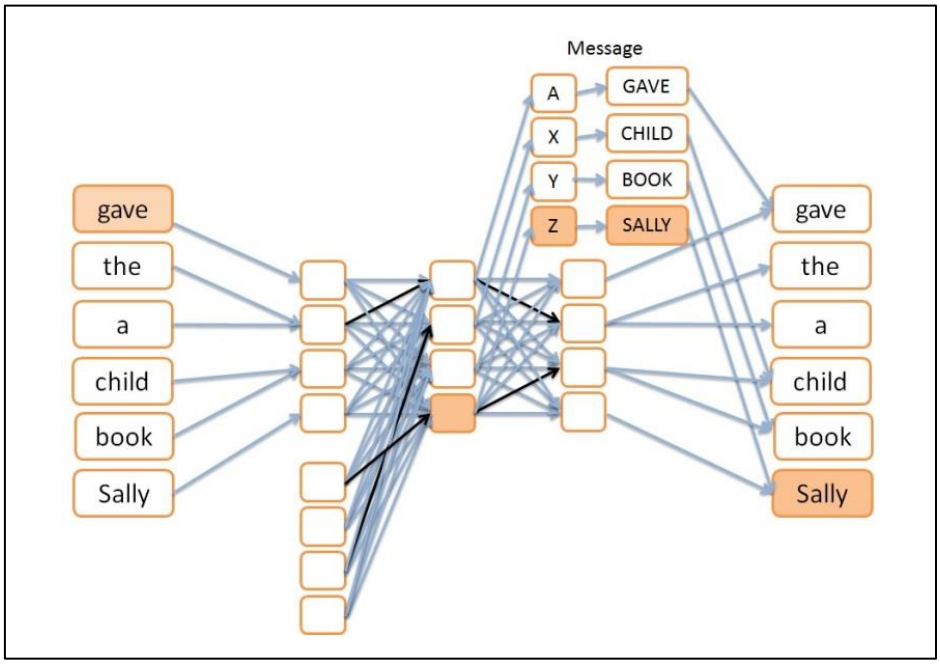

Figure 2.2 *Simplified Dual-path model: structural priming (taken from Chang et al., 2012)*

The prediction error for the prime is used to make changes to the weights in the network - some of which are made to abstract structural representations. Then, the model's meaning network is presented with a new target message. For instance, the model might be presented with a message that describes an event in which a book is transferred between a child and Sally (see Figure 2.2). The model recognises that this type of message can be described by either a DOD so that the recipient (Sally*)* immediately follows the verb *give* (e.g., *The child* ***gave Sally*** *a book*), or by a PD so that the theme (a book*)* immediately follows the verb *give* (e.g., *The child* ***gave a book*** *to Sally*). However, the slight changes in the connection weights (as a result of the prediction error caused when processing the prime sentence) are enough to bias the model's target description so that it is more likely to use the structure of the prime sentence - which in this case was a DOD. Thus, the Dual-path

model is able to show that DOD prime sentences like: *John threw the man a ball* will result in the production of a target sentence like: *The child gave Sally a book.*

2.4. What has structural priming told us about the nature of adult syntactic representations?

In short, the priming literature has been very informative about the nature of the mental representation of syntax in adults. As it stands, the results from the comprehension studies are still mixed; some have found evidence of priming only when there is verb overlap, while others have suggested that priming in comprehension is truly 'structural', and have shown that adults are primed even when prime and target verbs are different. Some have even provided mixed findings: Tooley & Bock (2014) found priming for transitive sentences when there was no lexical repetition, but priming for dative sentences only when prime and target sentences shared a verb. Thus, the comprehension literature still has some way to go to provide more conclusive answers about the representations that are employed during syntactic processing.

In comparison, robust and replicable abstract structural priming effects have been readily observed in production studies. These findings suggest that adults have abstract knowledge of syntax and that this knowledge does not depend on lexical items.

All the same, while adults have abstract representations of syntax, there is evidence to suggest that they also store links between these abstract

representations and verbs. This is because findings have shown that adults' syntactic choices are influenced by the identity of lexical items. For example, priming in adults is stronger when verbs are repeated across sentences (e.g., Branigan, Pickering, & Cleland, 2000; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; van Gompel, Arai, & Pearson, 2012). There is also growing evidence that the language that adults produce in structural priming tasks is influenced by their knowledge of verb-structure preferences (verb biases). For instance, although many dative verbs can occur in both double and prepositional object datives (e.g., *I gave him a cake/I gave a cake to him*), most of these verbs will tend to occur more often in one structure than another; the dative verb *give*, for example, tends to occur more often in double object than prepositional object dative structures (Campbell & Tomasello, 2001; Gries & Stefanowitsch, 2004). These verb biases (or preferred argument structure constraints) have been shown to affect how adults behave in priming studies. One example of this comes from a corpus analysis of English dative verbs by Gries (2005), who found that target verbs strongly associated with one structure resisted being primed into another structure. In another study by Coyle and Kaschak (2008), priming effects were found to be larger when the target verb was not strongly associated with one structure (i.e., when they were equi-biased). In other words, an adult's knowledge of a verb's preferred argument structure (i.e., whether this verb occurs more often in a DOD or a PD structure) influences how easily it is to prime that adult to produce the verb in that structure.

2.4.1. Prime surprisal: Evidence from experimental research and connectionist models

In addition, related research has suggested that the identity of the prime verb plays an important role in the size of the priming effect, such that priming is stronger when the prime verb's bias does not match the prime structure in which it is presented – an effect termed *prime surprisal* (Chang, Dell, & Bock, 2006). For example, when Jaeger and Snider (2007) re-analysed the dative structures in a corpus of speech by Bresnan, Cueni, Nikitina, and Baayen (2007), they found that priming was stronger for PD primes if the verb in that prime was DOD-biased (i.e., when prime verb bias and prime structure were mismatched). Similarly, when Fine and Jaeger (2013) re-analysed Thothathiri and Snedeker's (2008b) comprehension study, they reported that prime structures that were more surprising led to stronger expectations that that same structure would also be used in the target sentence. Jaeger and Snider (2013) also revealed that adults were more likely to be primed when the co-occurrence of the prime verb and prime structure was unexpected. Their corpus analysis study showed that adults were more strongly primed when DOD-biased prime verbs were presented in a PD prime structure. Similar effects have also been found in Dutch; in Bernolet and Hartsuiker's (2010) task, priming in adults was stronger when Dutch PD-biased verbs were presented in a DOD structure. In other words, the more unexpected (or surprising) a verb is in a prime sentence, the more likely participants are to be primed.

Along with the experimental findings, prime surprisal effects have been conceptualised in Chang, Dell, and Bock's (2006) Dual-path model. In the model, structural priming occurs because the syntax system generates a prediction about the next word and calculates the difference between the predicted word and the actual word. A fundamental assumption of the model is that learning and, thus, priming, only occurs when the system's expectations are not met. In other words, the weight changes that lead to structural priming will only happen when the model's prediction about the next word diverges from its expectations. When the next word is particularly unexpected, such as instances in which there is a mismatch between the structure bias of the prime verb and the structure of the prime sentence (e.g., a DOD-biased verb in a PD structure), then this surprisal can cause large weight changes that result in an even stronger structural priming effect. For example, if the model is presented with a PD prime sentence that contains a DOD-biased verb like *give* such as, *The boy gave a toy to Lizzie*, it will expect the post-verbal noun to be the recipient (Lizzie) and not the theme (a toy). This is because the model (like a human speaker) will have learned that *give* is DOD-biased and that the recipient usually follows this verb (e.g., *The boy gave Lizzie a toy*). Because the model's prediction about the next word is very different to the actual word, this results in greater error and greater weight changes to abstract structural representations. Consequently, the model is even more likely to use the same structure as the prime sentence.

2.4.1.1. Prime surprisal: Predictions and assumptions of the Dual-path model

Fundamental to the Dual-path model is that predictions are generated and syntactic representations are altered on the basis of individual words in sentences, and not on structures as a whole. This is because the model does not store representations of entire structures, but instead stores abstract representations of syntactic categories along with probabilistic information (based on previous experience and the current context) about how these categories are combined. Because of this, the model does not process entire sentences; processing happens incrementally on a word-by-word basis. This means that structural priming, and thus, prime surprisal effects, on this model, are not considered in terms of the frequency of entire structures in the language, but in terms of conditional probabilities between words. Put simply, the model works by asking the question, “Given my experience with the current word, X, and the current context, Y, what is the likelihood that the next word will be Z?”.

Take, for example, the DOD which is less frequent in the English language than the PD. A number of studies have revealed that structural priming effects are stronger for DOD primes than PD primes (e.g., Rowland et al., 2012). At first glance, then, we might attribute these stronger priming effects to prime surprisal because the DOD structure is less frequent (and, therefore, more unexpected) in the language. However, this is not how the Dual-path model works because it does not use the absolute frequency of the structure in the language to make its predictions; predictions are actually

made based on the conditional probabilities between words, and these probabilities will be determined by its experience with these words. Since the DOD is less frequent in the language, the model with have more experience with PD sentences in which an inanimate theme (e.g., *a letter*) tends to follow the verb (e.g., PD: *The man **posted a letter** to the woman*). Therefore, when the model processes a DOD prime, it will expect an inanimate theme after the verb (because of its previous experience with these types of transfer messages and lexical-structural combinations). However, this expectation will not be fulfilled, leading to large weight changes, and stronger priming (i.e., prime surprisal). This means that whilst we may, indeed, see surprisal effects in which speakers are primed more strongly by DOD sentences than PD sentences, this surprisal is based on predictions about how frequently lexical categories co-occur in the language, and not on how frequently structures appear in the language.

Just as the model does not consider prime surprisal in terms of the absolute frequency of structures in the language (e.g., hearing 100 DODs out of all of structures encountered), it does not conceptualise prime surprisal in terms of the relative frequency of alternative structures (e.g., hearing 100 DODs out of 500 datives encountered). What drives predictions and, thus determines the magnitude of structural priming effects, is the frequency of co-occurring lexical categories in the model's (or a speaker's) experience.

2.5. Why should we investigate structural priming in children and adults?

Taken together then, the research indicates that, for adults, knowledge about syntax is abstract but is also closely linked to and influenced by the verb lexicon. The findings from the developmental priming literature, however, leave us with some unanswered questions. The studies have told us that, like adults, three-year-old children have abstract syntactic representations, since they show evidence of abstract structural priming both in production and comprehension. However, these studies have not told us whether, like adults, children's representations are closely linked to the verb lexicon. Because of this, we are still unsure about how children's knowledge of syntactic structure is linked to their knowledge about verbs and how they behave. Further still, we do not really know how this relationship changes across development to become adult-like. This is primarily because studies have not directly compared children's and adults' responses using the same structural priming task. As a result, we have not been able to track when and how abstract syntactic representations and verb-structure links change over time. To accurately investigate this, we need to go beyond the previous studies and design a structural priming paradigm that tests both children and adults on the same task.

Until recently, many of the child priming studies have neglected to implement the controls employed in the adult literature. For example, in the adult studies, the prime sentence is often only presented once (e.g, van Gompel, Arai, & Pearson, 2012). Yet, in some cases, children are exposed to multiple primes (e.g., Thothathiri & Snedeker, 2008; Savage et al., 2003). In

the adult studies, the inclusion of filler sentences is quite common (e.g., Cleland & Pickering, 2006; Sturt, Kelley, & Dubey, 2010; Tooley & Bock, 2014; Traxler, Tooley, & Pickering, 2014), whereas these are often omitted in the child studies (e.g., Bencini & Valian, 2008; Savage et al., 2003). Whilst adults are usually exposed to all of the possible prime structures for that task, children are not. For example, in Pickering and Branigan's (1998) task, adults completed both DOD and PD prime fragments, whereas in Huttenlocher, Vasilyeva, and Shimpi's (2004) study, children were randomly assigned to receive either DOD or PD prime forms. Some child studies even include a "training" element that, arguably, may help to better substantiate the prime structure (e.g., Bencini & Valian, 2008; Savage et al., 2003). All of these differences in task design make it difficult to determine whether the priming effects in children are as robust as they are in adults, as well as making it a challenge to identify a pattern of syntactic development. So, to address this, we need a priming task that eliminates many of the potential confounds of the previous child studies by including in it important aspects typically used in the adult paradigms. Rowland, Chang, Ambridge, Pine and Lieven (2012) have done precisely this. They designed a task suitable for testing both children and adults, manipulating verb overlap across prime and target sentences to assess structural priming and the lexical boost across development. Children (aged 3-4 years and 5-6 years) and adults heard DOD and PD prime descriptions of cartoon animations before describing cartoons best described using a dative structure. They reported significant abstract structural priming effects in both children and adults: All age groups produced more DOD responses after a DOD prime than after a PD prime

even when the prime and the target included different verbs (e.g., *give-send*). From this, they concluded that by the age of three, a child's language learning mechanisms have experienced enough input to have built some form of abstract syntactic representation for the English dative. In contrast, when prime and target sentences shared a verb, the pattern of priming differed in children and adults; adults showed a substantially larger priming effect when there was verb overlap compared to when the prime and target verbs were different (a significant boost of 34%). This effect was only marginal in the 5-6 year olds (10%) and non-existent in the 3-4 year olds. In other words, the repetition of verbs across sentences did not boost the priming effect for the youngest age group in the same way that it did for adults. Using this methodology, we can investigate the way the relationship between syntactic representations and the verb lexicon develops.

2.6. Summary

To summarise, findings in the adult priming literature suggest that adults' syntactic representations are largely abstract, but that there is a close integration between these representations and individual verbs. The robustness and replicability of these findings mean that we have a fairly comprehensive picture of what adult syntactic knowledge is like and how this knowledge is linked to the adult verb lexicon. Our understanding of the way in which children's knowledge of structure is represented as well as how this information is linked to knowledge about individual verbs is still unclear. This is partly because the findings from the acquisition studies are conflicting

(e.g., Gertner, Fisher, & Eisengart, 2006, vs. Tomasello, 1992), but also because the child priming studies have tended to focus only on determining the abstractness of early representations at a particular age, and not on how these representations interact with the verb lexicon across development. The picture is also complicated by the fact that not all of the child priming studies have included the rigorous controls implemented in the adult priming studies, making it difficult to draw reliable conclusions about syntactic development.

Thus, to better inform the literature about the relationship between syntactic structure and the developing verb lexicon, the aim of thesis was to explore how lexical effects like verb overlap and verb bias affect structure choice in both children and adults. The present work investigated this by studying both children's and adults' responses in a series of structural priming tasks with particular focus on the role of the verb. This work goes beyond previous research by using a structural priming paradigm that allows testable predictions to be made about the development of syntax and the verb lexicon.

Given that few child studies have investigated the role of the verb in structural priming, and only one has demonstrated reliable evidence of structural priming in both children and adults on the same task, the next chapter tackles the question of when and how children develop knowledge of verb argument structure for the dative. The chapter first reports the results from study 3a: an analysis of the Manchester corpus conducted to identify the syntactic preferences (verb biases) of four familiar alternating dative

verbs in child-directed speech. It then reports the findings from study 3b: a structural priming study that investigated whether children (as young as 3;0) and adults' knowledge of the biases of these verbs influences their choice of prepositional and double object datives in a priming task.

Section 2: Experimental data

Chapter 3

When and how do children develop knowledge of verb argument structure? Evidence from verb bias effects in a structural priming task

Chapter 3: When and how do children develop knowledge of verb argument structure? Evidence from verb bias effects in a structural priming task

3.1. General introduction

In the previous chapter, we discussed how useful the priming literature has been for telling us what adults' syntactic knowledge is like. The findings from these studies have revealed that adults have abstract representations of syntactic structure (e.g., Bock, 1986; Cleland & Pickering, 2006; Noppeney & Price, 2004), but the identity of lexical items also influences the language that they produce. For instance, the priming effect is boosted when prime and target sentences share a verb (Pickering & Branigan, 1998; Jaeger & Snider, 2013), and adults' knowledge of a verb's preferred argument structure (verb bias) has been shown to influence their structure choice during a priming task. For example, the syntactic preference of the target verb can affect how easily adults are primed (target verb bias; Gries, 2005). The identity of the prime verb also seems to play a role such that priming is stronger when the prime verb's bias does not match the prime structure in which it is presented (prime surprisal; Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013). Not only do prime surprisal effects show that adult speakers store information about verb-syntactic preferences, they also suggest that adults make predictions about prime sentences based on their knowledge of these preferences: When these predictions are not met (i.e., when a verb is presented in an unexpected structure), prime surprisal works to boost the priming effect (Chang, Dell, & Bock, 2006). Taken together, the data show

that adults store links between verbs and the structures in which these verbs occur, and that these links can influence structural priming. Thus, for adults, there seems to be a close integration between their syntactic representations and the verb lexicon.

Conceptualising this relationship in children is not as straightforward. This is because, although structural priming has been used to investigate the nature of children's early syntactic representations (e.g., Bencini & Valian, 2008; Messenger, Branigan, & McLean, 2011; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007; Thothathiri & Snedeker, 2008a), these studies have tended to focus on determining the abstractness of children's early syntactic knowledge, and not on how this knowledge might interact with the verb lexicon across development. This approach has been a useful way of distinguishing between theories of early syntactic acquisition; the findings, for the most part, have provided strong support for early abstraction accounts, with children showing that they have acquired at least some abstract representations that enable them to generalise across sentences by around the age of three (though see Savage et al., 2003, for contradictory evidence). Nevertheless, this focus on the abstractness of early representations means that we know little about how lexical effects like verb overlap and verb bias influence structural priming across development. As such, an important question not addressed by these studies is when and how children's abstract knowledge of structure interacts with their knowledge about the behaviour of particular verbs (verb argument structure). Thus, unlike the adult priming literature, the child priming literature has little to say about when and how children learn to link their abstract syntactic representations to the

developing verb lexicon, and even less about the mechanisms that might mediate this relationship.

One exception to this pattern is a recent study by Rowland, Chang, Ambridge, Pine, and Lieven (2012). By investigating the lexical boost, using the same task to test both children and adults, they showed that it is possible to use structural priming to look at the way the relationship between syntactic representations and the verb lexicon develops. In their study, Rowland et al. found evidence of abstract priming in both children (aged 3-4 years and 5-6 years) and adults but the lexical boost did not emerge until relatively late. These findings have theoretical implications for our understanding of the relationship between abstract and lexical knowledge. Further still, these results show that lexical effects like verb overlap can be used to investigate the nature of young children's verb-structure links.

Another way of tapping into children's knowledge of the links between verbs and syntactic structure is to investigate the effect of verb bias on structural priming. So far, the results from verb bias studies in adults have told us that adults' abstract knowledge is closely linked to the verb lexicon; there is growing evidence that they are sensitive to both target verb bias and prime surprisal effects. Thus, by examining the effect of verb bias on structural priming in children and adults, we can assess when children's verb-structure links develop.

We can also capitalise on verb bias effects to examine how, as well as when, verb-structure links develop, as currently, the exact nature of the mechanism that children use to learn these links is not well understood. There are (at least) two possibilities: an error-based learning mechanism

(Rumelhart, Hinton, & Williams, 1986) implemented in Chang, Dell and Bock's (2006) Dual-Path model, in which structural predictions are made based on the verb, and the error (or mismatch between the predicted structure and the actual structure) is used to adjust the verb-structure connection weights, and an associative learning mechanism whereby the co-activation of a particular verb and structure strengthens the connection between that verb and that structure. Investigating how lexical boost and verb bias effects influence structural priming over development should allow us to adjudicate between these two possible means by which children link their knowledge about structure to their knowledge about verbs and how they behave.

The first aim of the study then, was to explore when young children develop verb-structure links, and, in doing so, investigate when these links change to become adult-like. The second aim of the study was to examine the nature of the mechanism that underlies the development of these verb-structure links. First, we discuss what lexical effects like verb overlap and verb bias can tell us about the nature of verb-structure links across development. We then explain how we can use these effects to examine how these links are developed.

3.1.1. When do children develop verb-structure links?

Rowland et al. (2012) found that only adults, not children, show lexical boost effects in structural priming tasks. On the face of it, this result might suggest that young children do not represent links between syntactic structures and the lexicon, and that these links develop slowly throughout

childhood. In other words, it may be that in three-year olds, these verb-structure links do not exist, or, at least, are not strong enough to influence syntactic choices in a priming paradigm. For example, it could be that children first build abstract representations of constructions (e.g., the dative construction), and only once these are built do they then establish links between these representations and individual verbs (Braine, 1971). Because this mapping between verb identity and syntactic structure happens on a verb-by-verb basis (as experience with different verbs accumulates), this process is relatively slow.

An alternative explanation, put forward by Chang, Dell, and Bock (2006), is that the lexical boost is the wrong tool for making inferences about the relationship between verbs and syntactic structure. According to these authors, abstract structural priming occurs as a consequence of a learning mechanism that makes small gradual changes in syntactic representations. Lexical boost effects, however, are too large to result from these types of changes; they result, instead from the speaker's explicit awareness of the repetition of lexical items across prime and target sentences (Chang, Janciauskas, & Fitz, 2012). The consequence is that lexical overlap acts as a cue in the retrieval of the explicit memory of the prime structure. Given that explicit memory increases with age (Naito, 1990; Sprondel, Kipp, & Mecklinger, 2011), the boost should also increase in line with the ability to form, store, and retrieve explicit memories. On this view, the lexical boost is small (or even absent) in young children and larger in adults, not because children do not have verb-structure links, but because they are less efficient at retrieving an explicit memory trace of the prime sentence.

Since there are two potential explanation of why adults, and not children, show increased priming when there is verb overlap, investigating the lexical boost alone does not allow us to determine whether or not children have adult-like verb-structure links. To do this, we need instead to examine whether knowledge of verb biases affects children's structural choices. There are two ways to do this; investigating target verb bias and prime verb bias.

So far, adult studies have shown that adults' knowledge of a target verb's preferred argument structure influences how easy it is to prime them to produce that verb in that structure (Gries, 2005). Thus, adults have verb-structure links that work to influence their structure choice during a priming task. If children have also established these verb-structure links, then we should expect to see target verb bias effects early in acquisition. If, however, children have not yet linked the relevant verbs with their argument structure preferences, then only adults should demonstrate target verb bias effects during a structural priming task.

Similarly, adults have been shown to be sensitive to prime surprisal; their knowledge of prime verb biases plays a role such that they show stronger priming when the prime verb's bias mismatches the structure in which it appears (e.g., DOD-biased verb in a PD structure). If, like adults, children have created links between verbs and syntactic structure, then verb-structure mismatches during a structural priming task should also lead to prime surprisal effects in children. If, however, they have not yet formed these verb-structure links, then we should only expect to see evidence of prime surprisal in adults. The first aim of the current study then, was to investigate

when children show evidence of target verb bias and prime surprisal effects in a structural priming task.

3.1.2. How do children develop verb-structure links?

We can also exploit verb bias effects to investigate how verb-structure links are developed. There are two potential mechanisms that are supported by computational, behavioural, and biological evidence. First, we consider the possibility that verb-structure links are created via a process of error-based learning, before turning to the alternate option: that these links are developed by means of an associative learning mechanism.

3.1.2.1. Error-based learning mechanisms and structural priming

On an error-based learning account (Rumelhart et al., 1986), the system generates a prediction, using the error mismatch between that prediction and the actual input in order to learn. This mechanism has been applied to syntax acquisition and structural priming in a connectionist model called the Dual-Path model (Chang et al., 2006). On this account, syntax learning occurs because the syntax system generates a prediction about the next word and uses the error that is calculated to make gradual changes in the weights that support syntactic knowledge in the system. These weight changes gradually converge on the representations that support adult-like sentence production. The model is tested for priming by presenting the prime sentence with error-based learning left ON. The prediction error for the prime is used to make changes to the weights in the network - some of

which are made to the model's abstract structural representations. These weight changes influence the model's description of the target, increasing the use of the same structure and thus, creating a structural priming effect.

The development of verb-structure links is explained by the same error-based learning mechanism in the Dual-Path model. Since the model generates predictions and alters syntactic representations on the basis of individual words in sentences, these weight changes enable the model to learn lexical (verb)-structure links at the same time as syntactic structure. Thus, verb-structure links are learnt in parallel with knowledge of abstract syntactic structure. This means that the Dual-Path model makes particular predictions about the development of verb-structure links, and how they affect performance in structural priming tasks. First, the account predicts that children will show abstract structural priming as soon as they have acquired abstract structures. This is because children learn syntactic categories which subsequently combine into syntactic structures from early in the acquisition process. Second, because this model predicts that verb-structure links are built by the same mechanism that learns abstract syntactic structure, children should show target verb bias and prime surprisal effects as soon as they demonstrate knowledge of abstract structural priming (i.e., at or soon after the age of three years, Rowland et al., 2012).

However, because, on this model, the lexical boost is governed by a different cognitive mechanism: explicit memory (Bock & Griffin, 2000; Chang, et al., 2006; Chang, Janciauskas, & Fitz, 2012), the model predicts that the lexical boost will, instead, be larger in adults than in children. In sum, the

model predicts that structural priming, verb bias and prime surprisal effects, but not the lexical boost, will be present from the age of three years.

3.1.2.2. Associative learning mechanisms and structural priming

In order to be explicit about what we mean by associative learning, we will focus on a type of associative learning called Hebbian learning (Munakata & Pfaffly, 2004). According to Hebb (1949), when one neuron A excites another neuron B (and as long as A is excited just before B), the strength of the connection weight between these neurons increases. In this way, persistent exposure to a particular pattern of activation in the input reinforces the responsiveness of a particular output neuron in the future. This type of learning is biologically plausible because it only depends on local changes to pairs of neurons, and the phenomenon of long-term potentiation is a biological instantiation of this mechanism (Bliss & Collingridge, 1993). This mechanism can be modelled by the statistical operation of correlation, which encodes the strength of the relationship between two variables. In correlation, the relationship between two variables is strengthened whenever a pair of data points is included that matches the overall correlation. Thus, a key feature of an associative learning account that models the development of verb-structure links is that changes in the strength of these links are driven solely by the input and are not sensitive to the strength of the weights. Put simply, this means that the amount by which a link is strengthened in response to new input is not affected by the previous input. This is in contrast to error-based learning, where weight changes in the model are only made when the model generates an incorrect prediction.

Pertinent to the present work, is the fact that Hebbian learning has been used to explain a wide range of empirical findings from the language acquisition literature. For example, the learning of word-concept links is a prototypical associative learning phenomenon, and there are many models that use Hebbian learning mechanisms to simulate this process; Samuelson (2002) used Contrastive Hebbian Learning to train a model to learn the relationship between referents, word forms, and syntactic information, and Li, Farkas, and MacWhinney (2004) used a self-organizing Hebbian mechanism to model how we could learn the links between lexical items and semantics. More recently, McMurray, Horst, and Samuelson (2012) showed that a model with Hebbian learning combined with dynamic referent selection can explain a wide range of developmental behavioural findings, such as fast mapping, and the vocabulary spurt (i.e., an increase in the rate of vocabulary development).

Associative learning can also be used to explain how children develop verb-structure links (see Alishahi & Stevenson, 2008, and Perfors, Tenenbaum, & Wonnacott, 2010, who instantiate this approach to learning the relation between verbs and structures in computational models). On this account, verbs and abstract structural representations are present from early in development, as is suggested by the abstract structural priming effects shown in the youngest children in Rowland et al. (2012). Each time a verb is heard with a particular syntactic structure (e.g., the dative), the link between that verb and that structure is strengthened by a fixed amount. The development of verb biases (verb argument structure) occurs because of the accumulation of multiple verb-structure experiences to create a bias for one

structure. Verb bias and lexical boost effects result from the same associative learning mechanism. On this mechanism, an existing verb-structure link is strengthened after a single prime trial (consistent with adult models of structural priming in which Hebbian association mechanisms are the basis for the lexical boost effect, Reitter, Keller, & Moore, 2011).

The associative learning model makes a number of predictions about the development of verb-structure links, and how they affect performance in structural priming tasks. Like the error-based learning account, the associative learning account predicts that verb-structure links will grow with development. However, unlike the error-based learning account, it predicts that the lexical boost and verb bias will develop in parallel, because they both stem from the same verb-structure links. In other words, on this account if three year olds show lexical boost effects, then they should also show target verb bias effects. Contrariwise, if three-year olds do not show lexical boost effects (as in Rowland et al., 2012), then they should not show target verb bias effects. Finally, an important feature of the associative learning account is that priming is independent of the strength of verb-structure links. This means that matching and mismatching conditions should prime to a similar extent. For example, if the prime has a PD structure, then the likelihood of also producing a target with a PD structure will increase by some amount (e.g., 5%). However, since the size of this priming effect is not influenced by the prime verb's bias, the increase in PD production for a PD prime with a DOD-biased verb will be the same for a PD prime with a PD-biased verb (e.g., 5%). This is different from the error-based learning account, where priming is stronger when the prime verb's bias mismatches the prime

structure (e.g., a DOD-biased verb in a PD structure might increase PD production by 7%). Thus, while the error-based learning account predicts prime surprisal, the associative learning account does not.

In sum, the child priming literature has little to say about when children learn to link their abstract syntactic representations to the developing verb lexicon, and even less about the mechanisms that might mediate this relationship. To explore this then, a priming task was designed to assess the impact of three lexical effects - verb overlap, target verb bias, and prime surprisal, on structural priming in both children and adults. By doing so, this allowed us to investigate: a) when and b) how children's verb-structure links develop.

In order to identify, first, the biases of the four familiar alternating dative verbs in child-directed speech to be used, we analysed the Manchester corpus (study 3a). Study 3a is presented first and is followed by our priming study (study 3b).

3.2. Study 3a: Introduction

Children's speech mirrors closely what they hear in the input; verbs used most often by children are those that are generally more frequent in the adult language (Campbell & Tomasello, 2001). Children also seem to show the same verb biases as the adults around them (Gropen et al., 1989). This indicates that adult's speech can be used to predict the verb biases that children might have.

Our first step was to select verbs for the study that fit the following criteria:

a. Verbs that allow alternation between the PD and DOD structure.
b. Verbs that are familiar to young children.
c. Verbs that are biased towards one structure (either PD or DOD).

We identified four of the six verbs used by Rowland et al (2012) as potentially fitting the criteria. These four verbs were: *bring*, *send*, *show*, and *give*. Both *bring* and *send* have been reported as being biased towards the PD structure (Campbell & Tomasello, 2001). That is, despite the fact that these verbs can also occur in the DOD structure (e.g., *The boy brought/sent his mother some milk*), they tend to occur more frequently in PD sentences (e.g., *The boy brought/sent some milk to his mother*). In comparison, *show* and *give* are more often produced in a DOD than a PD structure, and so are DOD-biased. However, to be confident that the biases reported in the literature were accurate, we decided to conduct our own corpus analysis on the Manchester corpus (MacWhinney, 2000). This corpus (available from the CHILDES database) contains the spontaneous speech of twelve monolingual English-speaking children and their mothers, all based in the Midlands or the North-West of England. This corpus was chosen because it was thought that the data would be representative of the region from where participants were to be recruited. The aim of the analysis, therefore, was to determine how often each of the four verbs was produced in each structure (PD and DOD) by each of the mothers, and to make sure that these verbs were heard enough by young children for them to be familiar.

3.3. Study 3a: Method

The first step was to generate a list of all of the instances in which each of the 12 mothers produced the verbs *bring*, *send, show,* and *give* in the dative structure. To do this, we used the computer program CLAN (MacWhinney, 2000). Dative utterances were retrieved from the corpus using a "freq" code run on the %mor: line (morphological coding line) so that only the appropriate information from the corpus was selected for analysis.

The initial extraction of dative utterances was based on the following criteria: an utterance was considered a DOD if it contained a verb followed (not necessarily immediately) by two noun phrases (NP); an utterance was considered a PD if it contained a verb, an NP, and a prepositional phrase headed by *to*. Although this produced a manageable corpus for manual analysis, this method, did not allow for the distinction between canonical and non-canonical dative utterances. For example, because the criteria for CLAN specified only that DOD utterances require a verb and two NPs, there were occasions when this condition was fulfilled but the alternating utterance was not a canonical dative. For instance, although '*Show Daddy what you do*' contains a verb (*show)* and two NPs (*Daddy* and *what*) as a DOD does, the equivalent PD form (e.g., *Show to Daddy what you do*) is not canonical. Utterances posed as questions (e.g., *What would that chicken give them in the mornings*?) were also considered non-canonical. As such, the next step was to further edit each of the 12 transcripts by hand to ensure that non-canonical forms were omitted from the final dataset, and that only canonical dative utterances were analysed.

Throughout the manual editing process, five regional colloquial uses with *give* and *show* were identified; these were uses where the preposition "to" was omitted (e.g., *Show it me* and *Give it him).* This omission of the preposition "to" is common in the Northern English dialect so utterances like *Show it (to) me* and *Give it (to) him* were coded as PD utterances[1].

3.4. Study 3a: Results

Table 3.1 shows the proportion of DOD and PD utterances, and the total number of dative utterances produced in each mother's speech for each verb. Raw values, showing the number of PD and DOD utterances produced, can be found in the Appendix.

One-tailed t-tests were run to determine the bias of each verb; the mean proportion of DOD utterances for each verb was compared with the probability of that verb appearing in either a DOD or PD structure by chance (i.e., 0.5). A verb that appeared in a DOD structure more than 50% of the time was considered DOD-biased, and a verb that appeared in a DOD-structure less than 50% of the time was considered PD-biased.

As predicted, the results showed that *bring* and *send* appeared in DOD utterances significantly less than 50% of the time (*bring*: M = 0.30 (0.27); *send*: M = 0.25 (0.31)), and so are PD-biased (*bring*: $t(11) = -2.57$, $p = .013$; *send*: $t(11) = -2.80$, $p = .009$). The verbs *show* and *give* appeared in DOD utterances significantly more than 50% of the time (*show*: M = 0.80 (0.21); *give*: M = 0.78 (0.11)) and are, therefore, DOD-biased (*show*: $t(11) = 4.99$, $p < .001$ *give*: $t(11) = 8.43$, $p < .000$).

[1] We also repeated the analysis with these forms excluded; this did not change the pattern of results so we have not reported this analysis here.

Table 3.1 *Proportion of PD and DOD utterances and total number of dative utterances in each mother's spontaneous speech to her child for each verb*

Mother of…	Bring		Send		Show		Give		Total dative utterances
	PD	DOD	PD	DOD	PD	DOD	PD	DOD	
Alice	0.67	0.33	1.00	0.00	0.05	0.95	0.12	0.88	66
Billy	0.80	0.20	0.33	0.67	0.22	0.78	0.17	0.83	78
Bob	0.63	0.38	0.00	0.00	0.20	0.80	0.18	0.82	108
Helen	0.00	1.00	1.00	0.00	0.15	0.85	0.31	0.69	51
Ivy	0.56	0.44	0.00	1.00	0.00	1.00	0.26	0.74	96
Jack	1.00	0.00	0.67	0.33	0.09	0.91	0.14	0.86	80
Lucy	0.67	0.33	1.00	0.00	0.67	0.33	0.44	0.56	91
Mary	0.67	0.33	0.67	0.33	0.33	0.67	0.07	0.93	177
Olga	0.82	0.18	1.00	0.00	0.04	0.96	0.15	0.85	124
Rebecca	1.00	0.00	0.80	0.20	0.17	0.83	0.23	0.77	78
Sid	1.00	0.00	0.75	0.25	0.00	1.00	0.18	0.82	34
Steve	0.62	0.38	0.80	0.20	0.50	0.50	0.41	0.59	86
Mean	**0.70**	**0.30**	**0.67**	**0.25**	**0.20**	**0.80**	**0.22**	**0.78**	
Total									**1069**

3.5. Study 3a: Discussion

The results showed that the dative verbs *bring* and *send* were produced less than 50% of the time in a DOD structure, and that *show* and *give* were produced more than 50% of the time in a DOD structure. These results replicate the findings from published corpora. For example, Snyder and Stromswold (1997) found that 73.2% of adult *give* utterances used the DOD structure, and Campbell and Tomasello (2001) found that adults produced

show in a DOD 80% of the time. The British National Corpus (The British National Corpus, 2007) reveals that *bring* and *send* are produced around 70% and 56% of the time as a PD respectively, matching what was found in our analysis. Thus, our corpus analysis confirmed that *bring* and *send* are PD-biased, and that *show* and *give* are DOD-biased, making them suitable for use in study 3b.

3.6. Study 3b: Introduction

Study 3b assessed the impact of three lexical effects - verb overlap, target verb bias, and prime surprisal - on structural priming in both children and adults. The first aim of the study was to explore when young children develop verb-structure links, and, in doing so, when these links change to become adult-like. The second aim of the study was to examine the nature of the mechanism that underlies the development of these verb-structure links.

With respect to the first aim, if children develop abstract structural knowledge before they link this knowledge to individual verbs, then we should see evidence of abstract structural priming in both children and adults. Children, however, should not show evidence of lexical boost, target verb bias, or prime surprisal effects because, unlike adults, they will not yet have created links between verbs and the structures in which these verbs can occur. Alternatively, it could be that children acquire abstract and lexical knowledge from early on, but that the lexical boost is not a reliable measure of verb-structure links (Chang et al., 2006). If this is the case, then we should also see abstract structural priming in both children and adults, and a lexical boost in adults and not children. However, because on this view, a

small or absent boost in children occurs because children do not yet have an adult-like explicit memory, and not because they have not yet linked verb identity and structure, we should also expect to see target verb bias and prime surprisal effects in children and adults.

Turning to the second aim, the study tested two mechanisms by which children might develop verb-structure links: an error-based learning mechanism, and an associative learning mechanism. If verb-structure links are created via error-based learning, we should see evidence of abstract structural priming at all ages. This is because the error-based learning account predicts that children acquire both abstract syntactic representations and knowledge of verb argument structure from early in acquisition. Thus, we should expect to see target verb bias and prime surprisal effects at all ages at which structural priming effects are seen. In contrast, the lexical boost should increase with age because this effect is the result of a separate explicit memory mechanism. If, however, verb-structure links are developed via an associative learning mechanism, we should also see abstract structural priming from an early age, but crucially, the lexical boost, verb bias and prime surprisal effects should develop in parallel, because they all stem from the development of verb-structure links.

Using a modified version of the bingo game priming paradigm used by Rowland et al. (2012), the current study tested for structural and verb-specific priming effects in young children (3-4 years), older children (5-6 years), and adults. First, we assessed whether we could replicate the findings of Rowland et al. by examining structural priming and the lexical boost in children and adults. Second, we tested whether children, like adults,

would show verb bias effects in priming tasks by exploring whether the size of the priming effect was influenced by the bias of the target verb. Third, we assessed whether children, like adults, would show evidence of prime surprisal. To do this we explored whether the priming effect was stronger when there was a mismatch between prime verb bias and prime syntactic structure (e.g., DOD-biased verb in a PD structure).

3.7. Study 3b: Method

3.7.1. Participants

A total of 183 participants was tested. One hundred and twenty-three monolingual English-speaking children were recruited from nurseries and schools in the Liverpool area. Sixty-three of these children (32 female) were between five and six years old (mean age 5;8, age range 5;0-6;11) and 55 children (33 female) were between three and four years old (mean age 4;0, age range 3;0-4;11). An additional five children from the 3-4 year old age group were tested but produced eight or more (over half) 'other' responses during the task and so were excluded from the final analysis. A further 60 monolingual English-speaking adults (42 female) were recruited from the University of Liverpool student participation pool. Participants were tested individually in either their nursery/classroom or in the language development laboratory at the University of Liverpool.

3.7.2. Design and Materials

3.7.2.1. Design

The study used a 3 x 2 x 2 x 2 x 2 mixed design. Age (3-4 year olds/5-6 year old/Adults) was the between-subjects variable[2]. The four within-subjects variables were Prime Type (DOD and PD), Verb Match (Different verb and Same verb condition), Prime Bias (DOD- and PD-biased verbs) and Target Bias (DOD- and PD-biased verbs). The dependent variable for the descriptive analysis was the proportion of dative responses that were DODs (i.e., a ratio of DOD responses over the sum of DOD and PD target responses). For the inferential analyses, the dependent variable was binary (1 = DOD, 0 = PD).

3.7.2.2. Visual stimuli

Sixty-four video cartoon animations were created in Anime Studio Pro and were presented in E-Prime 2.0. The cartoons included three pairs of donor and recipient characters that are familiar to young British children and have proper noun names: *Tigger and Piglet, Dora (the Explorer) and Boots,* and *Bob (the Builder) and Wendy*. A further three pairs of donor and recipient characters were referred to with determiner + noun NPs: *the prince and the princess, the king and the queen, the boy and the girl*. Donor and recipient characters were always paired together (e.g., *Wendy* was always paired with *Bob*, and *the prince* was always paired with *the princess*). A further five characters acted as objects and were referred to with non-definite determiner + noun NPs: *a cat, a baby, a fish, a puppy, a rabbit*. All of the characters

[2] Although descriptive analyses are presented by age-group, age was coded as a continuous variable. The 3-4 year olds, 5-6 year olds, and adults were coded as aged 3.5, 5.5, and 20 years, respectively.

were animate to prevent animacy contrasts between the object and recipient influencing syntactic structure, since DOD sentences tend to occur with animate recipients and inanimate objects.

Thirty-two of the animations depicted transfer actions that can be described with dative sentences. Thirty-two others were used as fillers and depicted non-causal actions that can be described with intransitive sentences. Eight of the animations that were used as fillers were also used in a practice session. Each prime picture was always paired with a target picture that included different characters from those in the prime. Animations also depicted the direction of motion of transfer actions equally often from right-to-left and from left-to-right to control for the possibility that direction of transfer would influence structure choice.

Bingo cards were created to match each video cartoon animation. Four bingo boards were created on which to place the cards during the 'game'. Two of these boards included a grid of four squares and were used in a practice session before the actual experiment. The other two boards were used in the experiment and contained nine squares.

3.7.2.3. Sentence stimuli

The four verbs used – *give*, *show*, *bring,* and *send* - are alternating dative verbs that are familiar to young children. Ninety-six different sentences, including 32 verb-stems, were created to describe the 64 video cartoon animations. Thirty-two of these sentences described thirty-two different cartoon animations (eight DOD sentences for each verb). These were used as primes and depicted transfer actions using a DOD structure (e.g., *Dora*

gave Boots a rabbit). A further 32 prime sentences described the same transfer actions but used the PD structure (e.g., *Dora gave a rabbit to Boots*). Thirty-two target verb-stems (eight verb-stems for each verb) were created (e.g., *The boy brought...*) in addition to 32 filler sentences, which used an intransitive structure (e.g., *The princess jumped)*.

Each verb was presented eight times per participant: four times in the prime sentence (twice in the PD structure and twice in the DOD structure) and four times in the target verb-stem. Each participant was exposed to 16 prime-target pairs, which alternated with filler-filler pairs to minimize priming effects between pairs. Overall, each participant was presented with, and produced, 64 sentences in total. No participant was asked to produce the same prime sentence twice and all participants were exposed to an equal number of prime-target pairs from each of the prime conditions.

We explored both lexically-specific and lexically-independent priming as a within-subjects variable so participants were exposed to sentences in which verbs were repeated across primes and targets and also sentences where the verbs in primes and targets were different. Pairs of characters appeared equally often in prime and target sentences and, to avoid lexical overlap (other than that of the verb), characters in primes were always different from the characters in the targets with which they were paired. Furthermore, primes that contained determiner noun phrases (e.g., *the princess*) were always followed by targets with proper noun phrases (e.g., *Wendy*), and vice versa, to limit the possibility that participants would be primed by the prosody of the prime sentence. Additionally, sentences were always presented in the past tense to avoid repetition of the regular

progressive (*–ing*) ending. Three of the verbs were irregular (*gave*, *sent*, *brought*) to avoid repetition of the regular past tense (*-ed*) ending.

To control for sentence-specific preferences, 12 counterbalance groups were created to ensure that: 1) sentences that appeared as a DOD prime in one counterbalance group appeared as a PD prime in another, and vice versa; 2) all characters in both prime and target sentences appeared equally often with each verb, and 3) each prime verb was paired with itself and the three remaining verbs equally often in target sentences. All sentences across counterbalanced groups were presented semi-randomly to ensure that participants could not predict the structure of consecutive prime sentences. This also enabled us to ensure that characters appearing in a filler-filler pair had not appeared in the preceding target sentence or in the following prime sentence.

3.7.3. Procedure

3.7.3.1. Children

The experiment used a paradigm adapted from Rowland et al. (2012), and was conducted in the form of a bingo game in which the experimenter and the child took turns to describe cartoon animations on a laptop computer to a confederate. The experimenter introduced all of the characters involved in the task to the child by showing them a selection of bingo cards on which these characters appeared. They then sat in front of the computer side by side, whilst the confederate sat opposite. The experimenter described the cartoon on the left-hand side of the screen (the prime sentence) and asked the child to repeat the prime sentence, addressing a hand puppet held by the

confederate. The child was then asked to produce a target sentence by describing a cartoon animation on the right-hand side of the screen. A stem-completion technique was used to ensure that the child's response contained the target verb, although the child was encouraged to produce responses in the form of whole sentences. For example, the experimenter would say *"Wendy showed..."*. The child would then complete the description of the animation using this target stem (e.g., either, *"Wendy showed a rabbit to Bob"* or *"Wendy showed Bob a rabbit")*. After each sentence, the confederate looked to see if he/she had the bingo card corresponding to that cartoon. If he/she did, the correct bingo card was given to the experimenter or child as appropriate.

Each dative prime-target pair was immediately followed by an intransitive filler-filler pair. The first person to fill the bingo grid with bingo cards was the winner of the game and the experiment was designed so that the participant always won. Before running the experiment using the nine-squared bingo board, a practice session using the four-squared board was carried out to ensure that the children understood the task.

3.7.3.2. Adults

The procedure for adult participants was identical to the procedure for child participants except that a) adults were told that we were investigating how well children could describe a variety of scenes using different words and that we needed adults as a comparison group, b) adults received explicit instructions to repeat the prime and to produce responses in the form of full

sentences, and c) adults did not have to direct their speech towards a hand puppet.

3.7.4. Coding

Target responses were recorded online by the experimenter using the keyboard response coding function of E-Prime 2.0 (the experimenter pressed ‘p’, ‘d’, or ‘o’ depending on whether the participant produced a PD, DOD, or ‘other’ response, respectively, and these responses were automatically recorded and collated into a data file by E-Prime). The experiment was also audiotaped, allowing the transcription and coding of the utterances off-line by the first author. A second coder rated 10% of the utterances, and Cohen’s (1960) kappa revealed very good inter-rater reliability: $\kappa = 0.97$ (Landis & Koch, 1977).

Many of the young children and some of the older children needed prompting by the experimenter to produce the prime and the entire target sentence correctly. Some of them, however, only produced partial target responses (e.g., they completed the stem without including the target verb). In order to capture these partial target responses, we employed three levels of coding: lax, intermediate, and strict. To qualify for lax coding, the prime sentence had to be repeated correctly but the participant might have received help to do this. In addition, the participant may not have produced the target verb or the entire target utterance, but may have instead just completed the target stem. To qualify for intermediate coding, the prime sentence had to be repeated correctly with the participant needing minimal help to do this. In addition, the entire target utterance was produced, but

prompting to do this may have been needed more than once. To qualify for strict coding, the prime and target sentence had to be produced correctly with no more than one prompt. A target response was considered a DOD if it contained the correct target verb followed by two noun phrases, and a PD if it contained the correct target verb followed by a noun phrase and a prepositional phrase headed by '*to'*. Responses coded as 'other' were those where: a) the participant failed to repeat the prime correctly (even after help), b) the participant produced a non-target verb and, c) the target sentence included the preposition '*at*' rather than '*to*'. Preliminary analysis revealed that all of the coding schemes generated very similar patterns of results, and so the following analyses are reported only on the strictly-coded data.[3.]

3.8. Study 3b: Results

In this study we wanted to 1) assess the relation between structural priming and the lexical boost across development, 2) explore whether the bias of the target verb influenced structural priming across development, and 3) investigate whether a mismatch between prime verb bias and prime structure (prime surprisal) influenced structural priming across development.

A variety of logistic mixed effect models were fitted to examine our data (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). All of the models were calculated using the *glmer* function of the *lme4* package in R (lme4: version 1.1-6; R Core Team, 2012). In all cases, the dependent measure was the production of double object dative structures (DOD = 1, PD = 0). All factors

[3] Under the lax coding scheme, 3-4-year olds, 5-6-year olds, and adults produced 13%, 3%, and 1% 'other' responses, respectively. Under the intermediate coding scheme, 3-4-year olds, 5-6-year olds, and adults produced 22%, 5%, and 3% 'other' responses respectively. Under the strict coding scheme, 3-4-year olds, 5-6-year olds, and adults produced 24%, 7%, and 3% 'other' responses, respectively.

were effect/sum coded (Wendorf, 2004), except for age in years, which was centred to reduce multi-collinearity (Neter, Wasserman, & Kutner, 1985). Maximal models were fitted and the random slope structure was simplified until the model converged following the procedure in Barr, Levy, Scheepers, and Tily (2013). Model comparison was used to compute chi-square and p-values.

3.8.1. Structural priming, the lexical boost, and target verb bias in children and adults

Analysis 1 tested whether we could replicate the findings of Rowland et al. by examining structural priming and the lexical boost in children and adults (aim 1), and whether the size of the priming effect was influenced by the bias of the target verb (aim 2).

Figure 3.1 shows the mean proportion of DOD responses after DOD and PD primes in the Different verb and the Same verb conditions for each age group. Figure 3.2 shows the same data as Figure 3.1 divided by Target Bias (DOD-biased/PD-biased) instead of prime type. Structural priming (figure 3.1) was demonstrated if there was a greater proportion of DOD responses after DOD primes than after PD primes. A lexical boost (figure 3.1) was demonstrated if there was a bigger priming effect in the Same verb condition than in the Different verb condition. Target verb bias (figure 3.2) was demonstrated if there was a higher proportion of DOD target responses with DOD-biased verbs, and a lower proportion with PD-biased verbs.

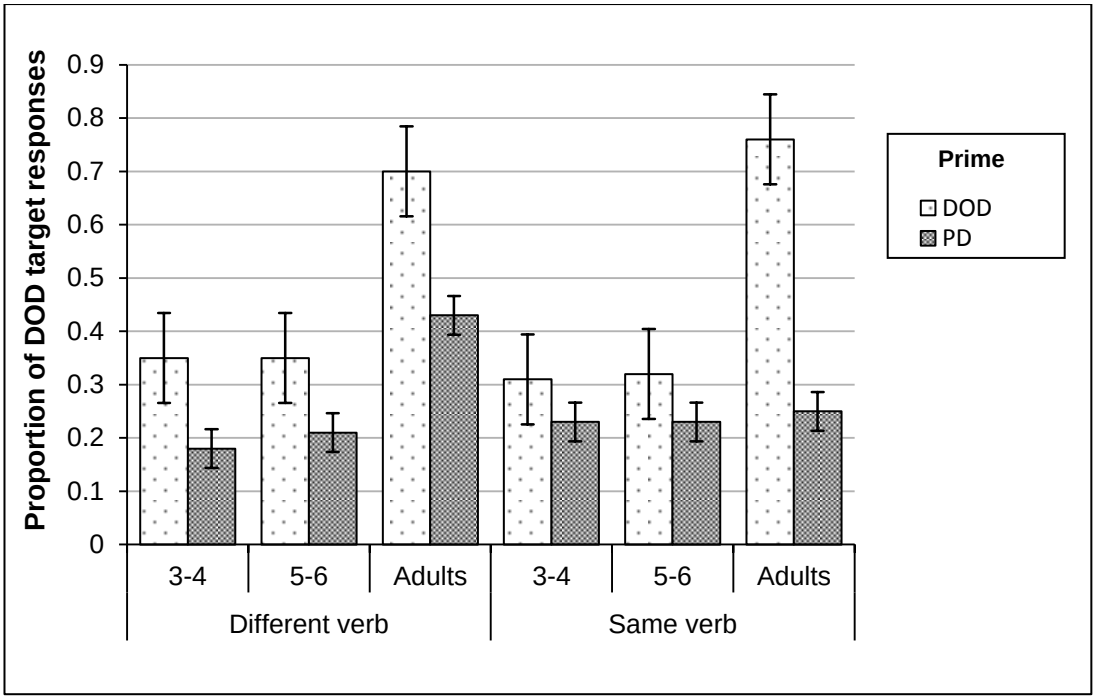

Figure 3.1 *Mean proportion of DOD responses after DOD and PD primes when prime and target verbs were different (Different verb) and the same (Same verb)*

Our first model included as fixed effects: a) Age (3-4 year olds/5-6 year old/Adults); b) Prime Type (DOD/PD); c) Verb Match (Different verb/Same verb); and d) Target Bias (DOD-biased verb/PD-biased verb). The model included by-subject random slopes for Target Bias. The results revealed a main effect of Prime Type ($\beta = 1.42$, $\chi^2(1) = 184$, $p < .001$), indicating that there was a structural priming effect; the participants produced more DOD responses after DOD primes than after PD primes. A main effect of Age ($\beta = 0.13$, $\chi^2(1) = 29.0$, $p < .001$) indicated that the likelihood of producing DOD responses overall increased with age. In addition, an interaction between Age and Prime Type ($\beta = 0.11$, $\chi^2(1) = 39.3$, $p < .001$) showed that, overall, the size of the priming effect increased with age. There was no interaction between Prime Type and Verb Match, but there was a three-way interaction

between Age, Prime Type, and Verb Match (β = 0.15, $\chi^2(1) = 21.4$, $p < .001$). The positive beta indicates that the lexical boost was larger in adults than in children.

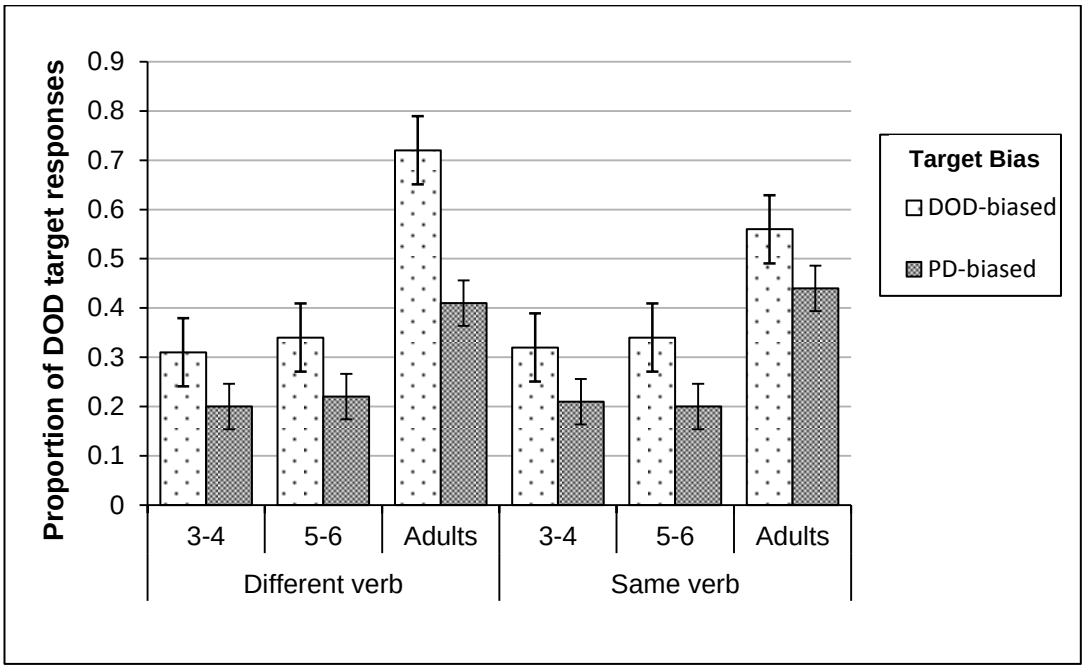

Figure 3.2 *Mean proportion of DOD responses in the Different and Same verb condition with DOD- and PD-biased target verbs (errors bars indicate standard error)*

With respect to target verb bias (Figure 3.2), a main effect of Target Bias (β = 1.19, $\chi^2(1) = 75.0$, $p < .001$) indicated that participants were more likely to produce DODs with DOD-biased target verbs than with PD-biased target verbs. There was also a three-way interaction between Age, Verb Match, and Target Bias (β = -0.08, $\chi^2(1) = 6.18$, $p < .05$), indicating that the effect of target verb bias was larger in adults than in children and that it differed across verb match conditions. Importantly, however, there was no

interaction between Target Bias and Prime Type, indicating that, although the bias of the target verb affected which structure the participants produced overall, it did not affect the size of the priming effect.

To explore both of the three-way interactions produced by the model, we fitted separate models to each age group. We also calculated effect sizes (Cohen's *d*) to allow direct comparison of groups while controlling for differences in sample size and variance (factoring out shared variation, as in Dunlap, Cortina, Vaslow, & Burke, 1996). Three separate models were run on each age group, and all models included by-subject random slopes for Target Bias. We will first review the results from each model for priming and the lexical boost to explore the interaction between Age, Prime Type, and Verb Match (Table 3.2). We will then separately review the results for Target Bias to explore the interaction between Age, Verb Match, and Target Bias (Table 3.3).

Table 3.2 *Size of priming effect in the Different verb and Same verb condition – calculated both as the proportion of DODs produced in each prime condition (difference score) and as effect sizes (Cohen's d)*

Age	Different verb			Same verb		
	Difference score	Standard error	Cohen's *d*	Difference score	Standard error	Cohen's *d*
3-4	0.15	0.049	0.45	0.03	0.041	0.08
5-6	0.14	0.030	0.42	0.06	0.023	0.17
Adults	0.27	0.048	0.90	0.50	0.044	1.86

Table 3.2 shows the size of the priming effect by age group and verb match condition calculated both as a difference score (% DOD responses produced after DOD primes minus % DOD responses produced after PD primes) and as Cohen's *d.* The 3-4 year olds showed a main effect of Prime Type (β = 0.85, $\chi^2(1) = 14.2$, $p < .001$), but no effect of Verb Match and no interaction between Prime Type and Verb Match. This means that the 3-4 year olds showed structural priming effects, but showed no lexical boost. Comparison of the effect sizes confirmed this interpretation; in fact, the effect size (Cohen's *d*) was smaller (not larger) in the Same verb (0.08) than in the Different verb condition (0.45). The data from the 5-6 year olds showed a similar pattern. There was a main effect of Prime Type (β = 0.98, $\chi^2(1) = 21.6$, $p < .001$), but no effect of Verb Match, and no interaction between Prime Type and Verb Match. Once again, comparison of the effect sizes confirmed this interpretation; there was structural priming but no lexical boost. The adults' data revealed a main effect of Prime Type (β = 2.25, $\chi^2(1) = 179.0$, $p < .001$) and a main effect of Verb Match (β = -0.42, $\chi^2(1) = 6.03$, $p < .01$). In contrast to the children however, there was a significant interaction between Prime Type and Verb Match (β = 1.29, $\chi^2(1) = 19.2$, $p < .001$), indicating that the size of the priming effect was bigger in the Same verb condition than in the Different verb condition. The comparison of effect sizes confirmed this interpretation; Verb overlap in the Same verb condition boosted the structural priming effect (by 23%). Thus, unlike the children, there was a large lexical boost effect in the adults.

Table 3.3 shows the size of the target verb bias effect by age group and verb match condition calculated both as a difference score and as Cohen's *d.*

Table 3.3 *Size of target verb bias effect in the Different verb and Same verb condition – calculated both as the proportion of DODs produced with DOD-biased target verbs minus the proportion of DODs produced with PD-biased target verbs (difference score) and as effect sizes (Cohen's d)*

Age	Different verb			Same verb		
	Difference score	Standard error	Cohen's *d*	Difference score	Standard error	Cohen's *d*
3-4	0.11	0.043	0.39	0.11	0.051	0.33
5-6	0.12	0.035	0.33	0.14	0.028	0.39
Adults	0.31	0.037	1.18	0.12	0.035	0.46

There was a main effect of Target Bias in all age groups; 3-4 year olds (β = 1.09, $\chi^2(1) = 10.5$, $p < .01$), 5-6 year olds (β = 1.40, $\chi^2(1) = 24.9$, $p < .001$) and adults (β = 1.35, $\chi^2(1) = 41.5$, $p < .001$). In other words, all age groups were influenced by the bias of the target verb, producing more DOD responses with DOD-biased target verbs than with PD-biased target verbs. There were no other main effects or interactions for the children, confirmed by the effect sizes, which are similar across the Same and Different verb conditions for both 3-4 and 5-6 year olds. However, the adults showed a significant interaction between Verb Match and Target Bias (β = -1.08, $\chi^2(1) = 9.76$, $p < .01$), indicating that the adults matched target verb bias less often in the Same verb condition than in the Different verb condition. Comparison of the effect sizes confirmed this interpretation; the effect size (Cohen's *d*) was smaller in the Same verb condition (0.46) than in the Different verb

condition (1.18). In other words, in the Same verb condition (presumably because the lexical boost dominated structural choice), the adults were less likely to default to matching the target verb biases. Thus, the three-way interaction of Age, Verb Match, and Target Bias shows that target verb bias increased over development, but that this effect was mediated by the lexical boost in the Same verb condition for the adults.

3.8.2. Prime surprisal in children and adults

Our third aim was to investigate whether children and adults were sensitive to prime surprisal. For this analysis, we created a Prime Bias Match variable. This allowed us to test whether the priming effect was larger when the prime verb bias mismatched the prime structure (e.g., Mismatch = a PD-biased verb in a DOD structure) compared to when the prime verb bias matched the prime structure (e.g., Match = a DOD-biased verb in a DOD structure). Analyses were conducted on the Different verb condition data only. This was to ensure that any difference in the priming effect between “Match” and “Mismatch” conditions was isolated to an effect of the prime sentence, and was not confounded by lexical boost effects. For example, the “Mismatch” sentences in the Same verb condition used the same prime and target verb. Thus, an increase in priming after sentences may have been interpreted as prime surprisal, when actually this boost in priming was a consequence of verb repetition, and vice versa. The model included as fixed effects: a) Age (3-4 year olds/5-6 year old/Adults), b) Prime Type (DOD/PD), c) Prime Bias Match (Match/Mismatch), and d) Target Bias (DOD-biased/PD-biased). It included by-subject random slopes for Prime Type and Target Bias.

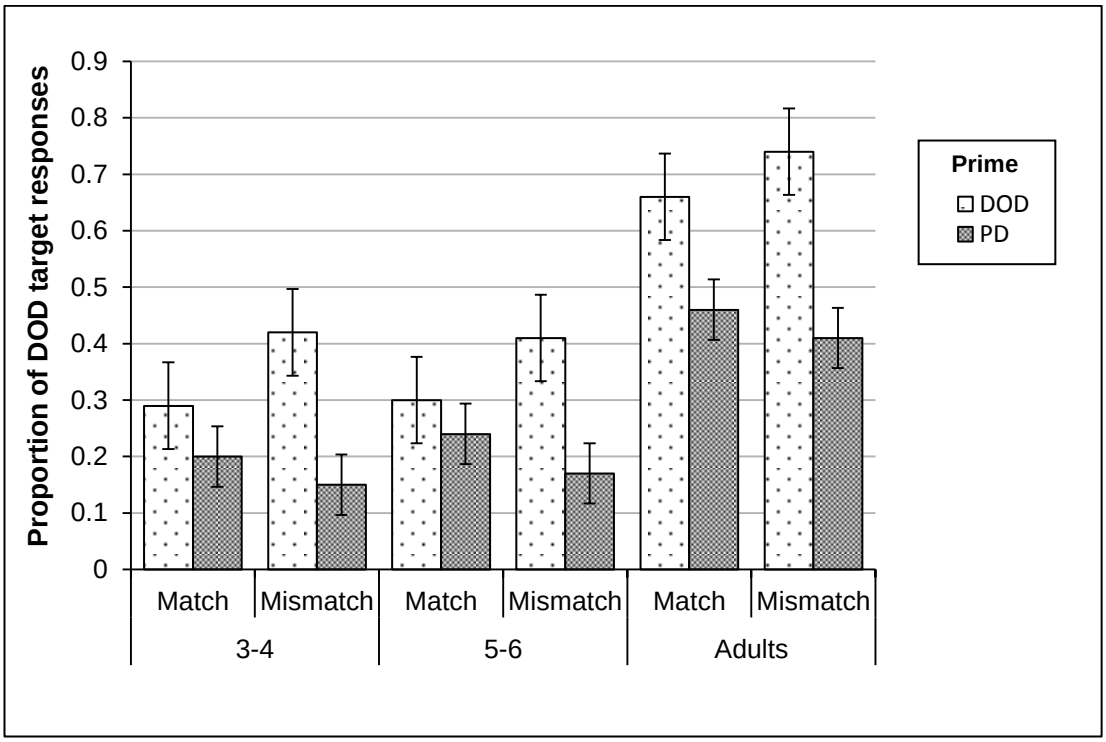

Figure 3.3 *Mean proportion of DOD responses when prime verb bias matched prime structure (Match), and when prime verb bias mismatched prime structure (Mismatch) (errors bars indicate standard error)*

We replicated many of the main effects and interactions we saw in analysis 1. There was a main effect of Prime Type (β = 1.42, $\chi^2(1) = 32.6$, $p < .001$), a main effect of Age (β = 0.14, $\chi^2(1) = 18.0$, $p < .001$), and a main effect of Target Bias (β = 1.28, $\chi^2(1) = 63.2$, $p < .001$). There was also a significant interaction between Age and Target Bias (β = 0.10, $\chi^2(1) = 11.1$, $p < .001$), with the positive beta again indicating that target verb bias effects were stronger in adults than in children. However, there was no interaction between Prime Type and Target Bias, or between Prime Bias Match and Target Bias. This indicates that the bias of the target verb did not interact with the priming effect (as in analysis 1) or with the effect of prime surprisal.

Importantly, there was a three-way interaction between Age, Prime Type, and Prime Bias Match (β = -0.10, $\chi^2(1) = 4.19$, $p < .05$). The negative beta for this interaction indicates that priming was stronger in the Mismatch condition compared to the Match condition and that this difference decreased with age (see Figure 3.3). No other interactions reached significance.

To explore the significant interaction between Age, Prime Type, and Prime Bias Match in more detail, we fitted separate models to each age group. As in analysis 1, we also calculated effect sizes (Cohen's *d*) to allow direct comparison of groups while controlling for differences in sample size and variance. Since Target Bias did not interact with any of the priming effects in the main analysis, we collapsed across Target Bias. All models included by-subject random slopes for Prime Type. Table 3.4 reports the size of the priming effect for each age group and verb condition calculated both as a difference score and as Cohen's *d.*

Table 3.4 *Size of priming effect when prime verb bias and structure were the same (Match), and when prime verb bias and prime structure were different (Mismatch) – calculated both as the difference between the proportion of DODs produced in each prime condition (difference score) and as effect sizes (Cohen's d)*

Age	Match			Mismatch		
	Difference score	Standard error	Cohen's *d*	Difference score	Standard error	Cohen's *d*
3-4	0.09	0.070	0.25	0.24	0.261	0.61
5-6	0.06	0.050	0.15	0.22	0.050	0.57
Adults	0.20	0.070	0.50	0.33	0.072	0.85

All age groups showed main effects of Prime Type, indicating that all ages were primed (as in analysis 1 above; 3-4 year olds; β = 1.26, $\chi^2(1) = 7.92$, $p < .01$; 5-6 year olds: β = 0.95, $\chi^2(1) = 8.29$, $p < .01$; adults: β = 1.38, $\chi^2(1) = 27.2$, $p < .001$). Both groups of children also showed a significant interaction between Prime Type and Prime Bias Match, indicating that there was significantly more priming in the Mismatch condition than in the Match condition (i.e. a prime surprisal effect; 3-4 year olds: β = 1.33, $\chi^2(1) = 4.58$, $p < .05$; 5-6 year olds: β = 1.18, $\chi^2(1) = 5.24$, $p < .05$). This was confirmed by the effect size analysis: the effect sizes in the Mismatch condition were more than double the size of the effect sizes in the Match condition for both the 3-4 year olds (Cohen's *d*: Mismatch = 0.61 vs Match = 0.25) and the 5-6 year olds (Cohen's *d*: Mismatch = 0.57 vs Match = 0.15).However, in adults, the difference in effect size was smaller (Cohen's *d*: Mismatch = 0.85 vs Match = 0.50), and was only marginally significant (β = 0.73, $\chi^2(1) = 2.87$, $p = .091$).

To summarise, as in previous studies (e.g., Rowland et al., 2012), there were significant structural priming effects at all ages, but the size of the lexical boost was larger in adults than in children. With respect to target verb bias, we found that all groups preferred to produce target sentences with the syntactic structures that matched the bias of the target verb and that this tendency was larger in adults than in children. This difference in verb bias knowledge was not seen in the Same verb condition potentially due to interference from the lexical boost. Finally, we found that priming was stronger when there was a mismatch between the prime verb's bias and its structure (prime surprisal), although the effect was only marginal in the

adults. Prime surprisal was strongest in the children and only marginal in the adults.

3.9. Study 3b: Discussion

In this study, we used a structural priming paradigm to investigate: a) when and b) how children's verb-structure links develop. We first assessed whether we could replicate the findings of Rowland et al., which showed that structural priming effects were present in children and adults, but that the lexical boost increased with age. Second, we tested whether children, like adults, were influenced by the argument structure bias of the target verb. Third, we examined whether children, like adults, were sensitive to prime surprisal.

We replicated the findings of Rowland et al., finding evidence for structural priming at all ages in that young children, older children, and adults were significantly more likely to produce DOD sentences (e.g., *Wendy gave Bob a rabbit*) after hearing and repeating DOD primes (e.g., *The boy sent the girl a fish*) than after PD primes (e.g., *The boy sent a fish to the girl*). These results provide additional support for the idea that, by the age of three, young children have built some form of abstract syntactic representation for the English dative construction that enables them to generalise across similarly-structured sentences (see also Bencini & Valian, 2008; Messenger, Branigan, McLean, & Sorace, 2012; Shimpi et al., 2007 for other evidence for early acquired knowledge). Like Rowland et al., we also observed a lexical boost that was larger in adults than in children: adults showed increased priming (23%) when the verb in the prime matched the verb in the target, but

3-4-year old and 5-6-year old children did not. In other words, although structural priming effects were apparent from age three to adulthood, the lexical boost was only apparent in adults.

We then tested when children, like adults, first demonstrated evidence that they were influenced by the bias of the target verb. Although target verb bias did not interact with the size of the priming effect for either children or adults, we found that it did affect which structure they produced; all age-groups produced more DOD responses with DOD-biased target verbs (*give*, *show*) than with PD-biased target verbs (*bring*, *send*). In other words, children as young as three years old already knew, and were influenced by, the alternation biases of the four dative target verbs used in this study, even though they did not exhibit the verb-based lexical boost. This effect of target verb bias, but not lexical boost, in the 3-4 year olds is consistent with the error-based learning account as instantiated in the Dual-Path model (Chang, Dell, & Bock, 2006) in which abstract and lexical knowledge are acquired from early on. These findings, however, do not fit with an account in which abstract knowledge is learned before this knowledge is linked to individual verbs, nor is it compatible with an associative learning mechanism which predicts a tight relationship between lexical boost and target verb bias throughout development.

Our final aim was to test when children, like adults, first demonstrated evidence of prime surprisal. We manipulated prime surprisal by having verbs with biases that matched or mismatched the prime structure; more priming is predicted when the verb's bias mismatches the structure in which it verb appears. Again, we found significant effects across all three age groups; 3-4

year olds, 5-6 year olds, and adults all showed stronger priming effects when there was a mismatch between the prime verb's bias and the prime structure (prime surprisal), although the difference was only marginal in the adults. In other words, the bias of the prime verb had an effect on the size of the priming effect and this was stronger in the children than in the adults. Again, the presence of prime surprisal in the 3-4 and 5-6 year olds, in the absence of a lexical boost is predicted by the error-based learning account, but not by an account in which abstract knowledge is acquired before the development of verb-structure links, nor an account that uses an associative learning mechanism to create these links.

Surprisal effects are difficult to explain in terms of the associative learning account, since it predicts that priming is independent of the strength of verb-structure links (i.e., matching and mismatching conditions should prime to a similar extent). The error-based learning mechanism in the Dual-Path model, however, directly predicts prime surprisal because on this model, priming is due to the mismatch in verb-structure prediction. For example, the model might predict that after a PD-biased (prime) verb sequence like, "*He sent the...*", the next word should be an inanimate word like *letter*. However, if the prime structure is actually a DOD structure, then the next word is more likely to be an animate word like *girl.* This mismatch between the predicted next word and the actual next word (error) is used to change the weights in the model so that it better predicts *girl* after "*He sent the...".* Since the weights in the model are initially set randomly, the model must learn about verb-syntactic preferences using error-based learning. In the model's equivalent of a three-year old, these preferences are established

by this point, and so prime surprisal effects should be seen early in acquisition.

3.9.1. Explaining the pattern of target verb bias and prime surprisal

Overall, our findings support the Dual-Path model which predicts that both abstract syntactic structures and verb-structure links are created early in the language acquisition process, and are a product of the same error-based learning mechanism. Structural priming, effects of target verb bias, and effects of prime verb bias (prime surprisal), but not lexical boost effects, were present at all three ages tested. However, there are two findings in our data that remain to be explained. First, adults were more strongly influenced by the bias of the target verb than children. Conversely, adults were less influenced by the bias of the prime verb than children. This apparent contradiction is difficult to explain if we assume that both effects come from the same source; the participants' knowledge of a verb's preferred argument structure, which both influences the choice in production of the target and generates the expectation that creates primes surprisal.

We speculate here that it is possible to explain this apparent contradiction in terms of the dynamics of the learning process. The increase in the effect of target verb bias can be explained by the accumulation of experience of verbs in their argument structure preferences: A verb's bias must be learned from the sample of verb-structure pairs in the input but, at any one time, the probability of a particular verb-structure pair occurring may not match the cumulative long-term probabilities (flipping a fair coin once will

never yield 0.5 heads). Nevertheless, whether a child's knowledge of a verb's syntactic preference begins with a random initial bias towards one structure (due to random initial connectivity in the brain) or with no bias at all, children should gradually accumulate evidence for these biases over development. For example, although the verb *throw* may have an overall bias towards the PD frame, there may be long periods of time in which *throw* is heard most often in a DOD structure. Early on in the learning process, these instances weaken the PD bias of the representation of the verb *throw* quite substantially, which means that in the beginning, syntactic representations are likely to be less stable. Thus, learning verb biases is a gradual process of accumulating evidence over time, which can be temporarily derailed by random fluctuations in the input. This can explain why target verb bias effects are smaller in young children than adults; within any one group of children at any one point in time, there will be substantial individual variation in the strength of the target verb bias, which leads to a smaller group effect. This difference in the strength of verb-structure links has been modelled in the Dual-Path model for the locative alternation (Twomey, Chang, & Ambridge, 2014).

The large prime surprisal effect in children, but the smaller effect in adults can be explained by changes in the magnitude of the learning rate, instantiated by a reduction in plasticity in connectionist models (Ellis & Lambon Ralph, 2000). Reduction in plasticity is important in these models to keep newly learned knowledge from overwriting older knowledge (catastrophic interference; McClelland, McNaughton, & O'Reilly, 1995). Chang et al. (2006) instantiated this reduction in plasticity by reducing the

learning rate over training. This has implications for priming, because in this model, priming involves the same error-based learning mechanism that is used for learning language. Faster learning rates lead to more substantial weight changes in response to error, and thus more prime surprisal. Thus, if the learning rate is higher early in development, this means that the effect of surprisal on priming will be larger early on. In other words, we see greater prime surprisal early in acquisition because initial learning is faster than later learning.

To clarify how these two effects could arise within a developmental account of language acquisition, we developed a simple dynamic systems model of verb bias acquisition. We gave the model 100 inputs for two verbs (A, B), which were coded as 1 for PD and 0 for DOD (PDINPUT). Each PDINPUT instance can be thought of as a PD or DOD prime structure and, through learning, long-term expectations for the verb-structure links are strengthened. When these changes accumulate over time and become stable, then we call this the verb's structural bias (Dell & Chang, 2014). To create verb biases, we specified that verb A occurred in a PD 80% of the time and verb B occurred in a PD 20% of the time. We also generated two random learners (learner 1 and learner 2). To implement the change in plasticity over development, a learning rate parameter was set to start at 0.1 and reduce to 0.01 in 100 steps. The model is governed by three equations. The first equation (1) implements error-based learning by updating the structural bias for the input verb V. This is done by adjusting the previous bias for that verb by the error between the previous bias and the present input (PD = 1, DOD = 0), multiplied by the learning rate (this only changes

the bias for the input verb; the biases for other verbs remain unchanged). Since it is standard to randomize weights initially in connectionist models (and the links between neurons in the brain are not set initially to some uniform strength), the second equation (2) sets the initial bias to a uniform random number between 0 and 1. The choice of structure that is produced is assumed to be a function of the bias of the verb that has been chosen (3). These equations were used to generate each random learner:

1) $BIAS_{V,T} = BIAS_{V,T-1} + (PDINPUT_T - BIAS_{V,T-1}) * LRATE_T$
2) $BIAS_{V,0} = UniformRandom\ (0, 1)$
3) $PDCHOICE_T = BIAS_{V,T}$ if verb is V

The initial bias (at time 0) is a random number between 0 and 1 and hence learner 2 has an initial bias of 0.79 for verb B, which is a bias for the PD. However, since verb B occurs in the PD 20% on average, the bias gradually decreases over development until the learner matches the adult's baseline bias. On the other hand, verb B in learner 1 is already close to the adult level (0.24, DOD-biased) at the start of development. However, due to a random run of PDs early in development, the bias is moved first towards the PD before returning to the adult level.

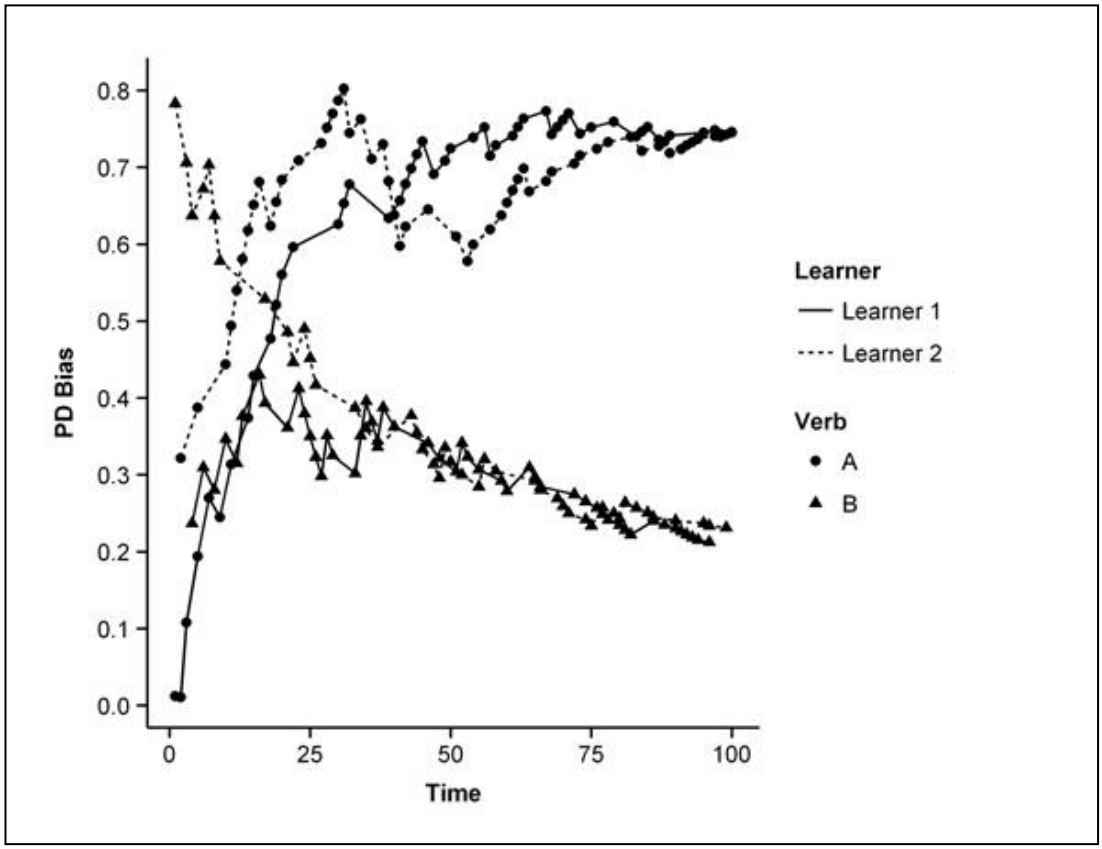

Figure 3.4 *Development of target verb bias for two verbs (A and B) over 100 exemplars for two hypothetical learners (learner 1 and learner 2)*

Figure 3.4 shows that, in this model, although early verb biases might not match adult biases, the gradual learning of adult biases can explain the age-related differences in the effect of target bias in our study. The variable learning rate in the figure also explains why prime surprisal effects are larger early in development. The learning rate starts off high and decreases over development, which means that early verb biases are affected more substantially by the prime structure than later verb biases (i.e., vertical displacement is greater). For example, for verb A, learner 2 starts off with a bias of 0.31 but, once the first PD is experienced, the bias increases by 0.08 because the learning rate is high. Later in development, the bias changes by

only 0.01 because the learning rate is lower. This explains why prime surprisal effects are larger earlier in development.[4]

The dynamic systems model helps us to understand how a model that allows verb-structure representations to change over development could provide an explicit account of the behavioural changes in this study. Although this is motivated by assumptions in connectionist models of development, it is consistent with the literature on the critical/sensitive period. For example, language learning ability is strongly associated with the age that language learning starts, even when the amount of input is controlled (Johnson & Newport, 1989; Lenneberg, 1967; Mayberry, 2007), which supports the view that the learning rate may change with age. The fact that critical/sensitive periods exist in many domains (e.g., Crawford, Harwerth, Smith, & von Noorden, 1996; Daw, 1994; Katz & Shatz, 1996; Weisel & Hubel, 1965; Kral & Sharma, 2012) suggests that these learning rate changes may be governed by neural mechanisms that are not specific to language learning (e.g., myelination, axon elaboration, synapse elimination, Knudsen, 2004). While the assumptions about learning rates help to explain the behavioural data in this study, they also show how structural priming may be related to neural mechanisms that support changes in plasticity over development.

3.10. Study 3b: Summary and conclusion

Exploring the effect of verb-syntactic preferences on structural priming in three age groups allowed us to assess when children develop verb-structure links and to test two possible learning mechanisms that might be involved in

[4] A faster learning rate implemented in a Hebbian mechanism would lead to more priming in both Match and Mismatch conditions.

the development of these links. Although the lexical boost was apparent only in adults, the identity of the target verb (target verb bias) and the prime verb (prime surprisal) influenced both children's and adults' structure choice from the earliest age tested. Thus, our results suggest that children acquire abstract knowledge of structure and develop knowledge about verb-argument structure preferences early in acquisition. However, children's performance was not adult-like; the effect sizes for target verb bias was larger in adults than in children, and for prime surprisal was larger in children than in adults. Taken as a whole, the findings leads us to propose that the process of verb argument structure learning is best explained by a mechanism that uses error-based learning with a variable learning rate.

One unexpected result was that children showed bigger prime surprisal effects than adults. We have provided one possible solution above, in terms of variable learning rates across acquisition. Another possibility, though, is that adults did not show evidence of prime surprisal because the verbs that were used in the study are too frequent in both DOD and PD structures for them to be unexpected in either. So, the difference in the size of the prime surprisal effects that we saw might not be a consequence of a variable learning rate, but could be the result of adults' familiarity with these verbs in both argument structures. To test this then, the next chapter investigated whether adults show bigger prime surprisal effects with verbs that are less frequent in the input.

Chapter 4

The effect of verb frequency on structural priming in adults

Chapter 4: The effect of verb frequency on structural priming in adults

4.1. Study 4a: Introduction

In chapter 3, we investigated when and how children learn to link their abstract syntactic representations to the developing verb lexicon. We found that, although only adults showed evidence of a lexical boost, both children and adults were sensitive to the target verb (target verb bias) and the prime verb (prime surprisal). As such, we suggested that children acquire abstract knowledge of structure, and develop links between this knowedge and verbs early in acquisition. We also found that while target verb bias was larger in adults than in children, prime surprisal was larger in children than in adults. One explanation that we offered for this pattern of results was that verb-structure links are developed by means of an error-based learning mechanism with a variable learning rate. In this type of mechanism, an initial high learning rate would cause large fluctuations in children's early verb biases but smaller changes in adult verb biases. This can explain why we saw larger prime surprisal effects in children than we did in adults. Another possibility, however, is that the adults in our study were simply too familiar with the verbs in both the DOD and PD structure for them to be surprising in either. For example, even though the verb *give* is DOD-biased, adults will, presumably, have heard *give* more often than children in its dispreferred structure (i.e., PD structure; *Wendy gave a dog to Bob*). Thus, adults' familiarity with the prime and target verbs in our previous study (and not an error-based learning mechanism with a variable learning rate) could be responsible for our earlier findings. One way to test this would be to

investigate whether adults show larger prime surprisal effects with verbs that are less familiar to them. The current study examined just this: using a structural priming paradigm, we examined the effect of verb bias on structural priming in adults with low-frequency verbs.

The idea that speakers are sensitive to the distributional information to which they are exposed is not an unfamiliar one. For example, research has shown that the frequency with which children hear verbs in their particular argument structures influences how they then use these verbs in experimental tasks (Matthews, Lieven, Theakston, & Tomasello, 2005). Findings have also shown that adults are able to monitor the transitional probabilities between syllables and that these distributional cues are important for word segmentation (Saffran, Aslin, & Newport, 1996). In addition, frequency effects are well-documented across other linguistic domains including in sentence comprehension (e.g., Juliano & Tanenhaus, 1993), in the acquisition of inflectional endings (e.g., Dąbrowska, 2008), and in adults' judgements of the grammaticality of overgeneralisation errors (e.g., Ambridge, Pine, Rowland, & Chang, 2012; Ambridge, Pine, Rowland, & Young, 2008; Stefanowitsch, 2008; Theakston, 2004; see Ambridge, Rowland, Theakston, & Kidd, in press, for a review of frequency effects in acquisition).

Further still, the frequency with which a verb appears in a particular syntactic structure has also been shown to influence structure choice in adults. As discussed in the previous chapter, behavioural evidence has revealed that structural priming is stronger when there is a mismatch between the bias of the prime verb and the structure in which it appears – an

effect called prime surprisal (Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013). These prime surprisal effects have also been simulated in the Dual-path model - a frequency-based connectionist model that conceptualises syntactic processing and development in terms of error-driven learning (Chang, Dell, & Bock, 2006). Because the model tracks the frequency with which syntactic categories co-occur, it develops representations based on the semantic and structural properties of verbs and, as a result, is able to make frequency-based predictions about the upcoming words in a sentence. Thus, not only does the research indicate that adults are statistical learners, and that this has consequences for how they store and represent syntactic information, but it also suggests that they make use of highly predictive mechanisms for processing language. Given this, it is surprising that structural priming effects have rarely been interpreted in the light of lexical effects such as verb frequency and verb bias.

One recent study by Ivanova, Pickering, Branigan, McLean, and Costa (2012), however, has touched on the issue of verb frequency by priming adults with verbs that they have never heard before. In their task, adults read dative primes containing novel verbs (e.g., *The waitress brunks the book to the monk*) and dative primes containing known verbs (e.g., *The waitress chucks the book to the monk*), before describing target pictures with known dative verbs (e.g., *The prisoner gives the ball to the swimmer*). Ivanova et al. found that, despite the fact that these novel verbs had had no entries in the lexicon, adults were primed just as much by sentences with novel verbs as they were by sentences with known verbs. Not only do these results suggest that adults have similar syntactic representations for both

anomalous and well-formed sentences, but they also suggest that adults' processing of anomalous sentences to produce well-formed sentences is not dependent on lexical information. Thus, the structural priming literature is beginning to gather evidence about how lexical effects like verb frequency impact on the way in which syntax is represented and processed. There is, however, room for further exploration – especially since little work has investigated whether both verb frequency and verb bias affect adults' responses in structural priming tasks.

4.1.1. The current study

The current study, therefore, used structural priming to further investigate how adults' lexical knowledge is linked to their knowledge about syntactic structure. To do this, we examined the impact of two lexical effects, verb frequency and verb bias, on adults' responses in a structural priming task. In the previous chapter, we tested whether adults were sensitive to verb-structure mismatches with verbs that are heard fairly often in the input. In this study, we tested whether adults also show sensitivity to verb-structure mismatches, but instead with verbs that are less familiar to them.

As a pre-requisite of testing this aim, the study first assessed whether adults show evidence of abstract structural priming with low-frequency DOD- and PD-biased verbs (aim 1). That is, are adults more likely to produce DOD target responses after DOD primes, than after PD primes? It is well-reported that adults have abstract representations of the dative structure that enable them to generalise across sentences with high-frequency dative verbs (Bock,

1986; Rowland et al., 2012). Findings have also revealed that adults are primed by sentences containing novel verbs just as much as they are by sentences containing known verbs (Ivanova et al., 2012). Given that adults have abstract representations that do not appear to rely on lexical information, we should expect the adults in this study to show evidence of abstract structural priming with low-frequency verbs.

Second (aim 2), we examined whether adults show prime surprisal effects with low-frequency verbs, and also compared whether the size of these effects is larger than those reported in our previous study. Despite emerging evidence showing that adults are sensitive to verb-structure mismatches (Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013), our previous study revealed only a marginal prime surprisal effect in adults, a much smaller effect than in children. One possible explanation for the size of this effect is that the prime sentences in our task were not surprising because the verbs used are ones heard too frequently in both DOD and PD structures by adults to be unexpected in either. A prime sentence containing a mismatch between a prime verb's bias and its structure might be more unexpected with infrequent verbs. We might, therefore, expect prime surprisal effects to be larger with low-frequency verbs than with high-frequency verbs.

4.2. Study 4a: Method

4.2.1. Participants

A total of 25 monolingual English-speaking adults (16 females) were tested. These participants were recruited from the University of Liverpool student

participation pool and were tested individually in the language development laboratory at the University of Liverpool.

4.2.2. Design and Materials

4.2.2.1. Design

The study used a 2 x 2 design. The two within-subjects variables were Prime Type (DOD and PD) and Prime Bias (DOD- and PD-biased verbs). As before, the dependent variable for the descriptive analysis was the proportion of dative responses that were DODs (a ratio of DOD responses over the sum of DOD and PD responses). For the inferential analyses, the dependent variable was binary (1 = DOD, 0 = PD).

4.2.2.2. Visual stimuli

Seventy-two still cartoon images were designed and presented in E-Prime 2.0. The cartoons included characters referred to with determiner + noun NPs (e.g., *The nurse; the chef; the boy*), as well as objects referred to with non-definite determiner + noun NPs (e.g., *a ring; a book; an ice-cream*).

Forty-eight cartoons depicted transfer actions that can be described with dative sentences. Twenty-four cartoons were used as fillers and depicted non-causal actions that can be described with intransitive sentences. Eight of the images that were used as fillers were also used in a practice session. Each prime picture was always paired with a target picture that included different characters from those in the prime. As before, images depicted the direction of motion of transfer actions equally often from right-to-

left and from left-to-right to control for the possibility that direction of transfer could influence structure choice.

4.2.2.3. Sentence stimuli

The 12 prime verbs used in this study are grammatical in both the DOD and PD structure. These verbs were selected because analysis of the British National Corpus (BNC) indicates that they have a low type frequency, and that they are also biased towards one variant of the dative over another; *promise*, *award*, *chuck*, *loan*, *serve* and *read* are biased towards the DOD structure, while *fling*, *issue*, *kick*, *lob*, *post*, and *write* are biased towards the PD structure. All prime verbs were paired with six target verbs also low in frequency: *fax*, *feed*, *flick*, *throw*, *toss*, and *slide*. Importantly, the target verbs used are reported in the BNC as appearing equally often in both the DOD and PD structure (i.e., they are equi-biased). Previous findings have shown that the identity of the target verb can influence the priming effect; target verbs strongly associated with one structure are more difficult to prime into another (Gries, 2005). This study focused on the impact of the identity of the prime verb, and not on that of the target verb. We, therefore, chose to pair prime verbs with equi-biased target verbs which are associated with the DOD and PD structure to a similar extent. We considered that by doing this, we could attribute any differences in the size of the priming effect to the bias of the prime, rather than the target, verb.

Forty-eight different dative sentences and 24 verb stems (e.g., *The boy faxed…*) were created to describe the 48 cartoons depicting transfer actions. Twenty-four of these cartoons (two cartoons per verb) were

described by 24 prime sentences using a DOD structure (e.g., *The waitress served the boy a cake*). A further 24 prime sentences described the same cartoons but used the PD structure (e.g., *The waitress served a cake to the boy*). Twenty-four target verb-stems (four verb-stems for each verb) were created, in addition to 24 filler sentences which used an intransitive structure (e.g. *The man was swimming)*.

Each verb was presented twice per participant: once each in a DOD structure and PD structure. Each participant was exposed to 24 prime-target pairs, interspersed with 24 filler-filler pairs. Fillers were used to minimize priming effects between pairs. No participant was asked to produce the same prime sentence twice.

As the study focused on exploring lexically-independent priming, prime verbs were always paired with different target verbs. To avoid lexical overlap, characters in prime sentences were always paired with target sentences that included different characters. Sentences were always presented in the past tense to avoid phonological overlap between primes and targets.

To control for sentence-specific preferences, 12 counterbalance groups were created to ensure that: 1) sentences that appeared as a DOD prime in one counterbalance group appeared as a PD prime in another, and vice versa; and 2) each prime verb was paired with the six target verbs equally as often. All sentences across counterbalanced groups were presented semi-randomly to ensure that participants could not predict the structure of consecutive prime sentences. This also ensured that characters

appearing in a filler-filler pair would not have appeared in the preceding target sentence or in the following prime sentence.

4.2.3. Procedure

The study was disguised as a memory task; the experimenter informed the participant that they were going to take part in a game that tested their memory for describing pictures. The participant was told that they would both take turns to describe cartoon images on a computer, and that at the end, a test would be conducted to see how many of the cartoons the participant could remember.

4.2.3.1. Structural priming task

The experimenter and the participant took turns in describing cartoon images on a laptop computer. Both the experimenter and the participant sat side-by-side in front of the computer, with the experimenter on the left and the participant on the right. The experimenter described the image on the left-hand side of the screen (the prime sentence) using the verb presented above the image and then asked the participant to repeat the prime sentence. Participants were told that repeating the sentence would help their explicit memory for the test at the end. The participant was then asked to produce a target sentence by describing the image on the right-hand side of the screen. The verb to describe the action was presented above the image to ensure that the target sentence contained the correct target verb.

To ensure that the participant understood the task, a practice session was carried out. During this session, the experimenter and the participant

alternated in describing four pairs of images that depicted non-causal events designed to elicit intransitive responses only. For example, if the experimenter's image was of a clown crying with the verb *crying* above it, then the experimenter said, "*The clown was crying"*, and this was repeated by the participant. Then, if the paired target image was of a boy cycling, with the verb *cycling* above, the expected response from the participant was, "*The boy was cycling"*. Once satisfied that the participant understood the procedure, the experimenter began the test session in which they alternated in describing cartoon images depicting events of transfer best described using dative sentences. Each dative prime-target pair was immediately followed by an intransitive filler-filler pair. Before beginning the test session, the participant was reminded that they would complete a memory test at the end, and that they should focus on remembering as many of the images as possible.

4.2.3.2. Memory task

Immediately after the priming task, participants took part in a memory task in which they verbally stated whether or not a series of cartoon images had appeared in the previous task. Thirty cartoon images were presented sequentially using Microsoft Powerpoint 2007 on the same laptop as in the previous task. Twenty of these cartoons were those that had been seen earlier, while 10 had not been seen before. The experimenter asked whether or not the participant remembered seeing the image (e.g., *Did you see this one: The boy flung the acorn to the squirrel?*), and the participant stated

either *yes* or *no*. Their answers were recorded, but these data were not used in the analysis.

The experiment was audio-taped so that the utterances could be transcribed and coded off-line. The strict coding scheme employed was based on the completeness of target sentences and on the accuracy of prime sentence repetition. To qualify for strict coding, a target response was considered a DOD if it contained the correct target verb followed by two noun phrases, and a PD if it contained the correct target verb followed by a noun phrase and a prepositional phrase headed by '*to'.* Any case in which a participant did not repeat the prime sentence accurately, or did not produce a full dative sentence with the correct target verb was classed as 'Other' (16% of target responses were coded as 'Other')[1].

4.3. Study 4a: Results

The aims of the present study were: 1) to assess whether adults show evidence of structural priming with low-frequency biased dative verbs, and 2) to explore whether adults are sensitive to verb-structure mismatches with low-frequency biased dative verbs.

A variety of logistic mixed effect models were fitted to examine the data (Baayen, Davidson, & Bates, 2008; Jaeger, 2008), all of which were calculated using the *glmer* function of the *lme4* package in R (lme4: version 1.1-6; R Core Team, 2012). The dependent measure was the structure produced by the participant (DOD = 1, PD = 0). All factors were effect/sum

[1]The most common cases in which a target response was coded as 'Other' were those where the participant used an incorrect target verb, or used the preposition, 'at' instead of, 'to'. The latter especially occurred with the verbs *flick*, *throw*, and *toss* since these verbs also take 'at' as a complement (e.g., *The chef tossed a pizza <u>at</u> the boy*, instead of, *The chef tossed a pizza <u>to</u> the boy*).

coded (Wendorf, 2004). Model comparison was used to compute chi-square and p-values.

4.3.1. Structural priming with low frequency verbs

The first analysis tested the first aim: whether adults show evidence of structural priming with sentences containing low-frequency dative biased verbs. For descriptive analyses, the mean number of DOD, PD, and Other responses was calculated (see Table 4.1).

Table 4.1 *Mean (SD) number of DOD, PD, and other responses after DOD and PD primes*

	Mean number of responses		
Prime type	**DOD**	**PD**	**Other**
DOD	3.04 (1.47)	6.96 (2.11)	1.96 (1.66)
PD	1.48 (0.92)	8.57 (2.13)	2.00 (1.86)

On average, the adults produced more than twice as many DOD responses after DOD primes than after PD primes. The first model included as fixed effects: a) Prime Type (DOD/PD), and b) Prime Bias (DOD-biased verb/PD-biased verb). The model included by-subject random slopes for Prime Type, Prime Bias and Prime Type crossed with Prime Bias.

The results revealed a main effect of Prime Type ($\beta = 1.00$, $\chi^2(1) = 11.9$, $p < .001$), indicating that adults produced significantly more DOD responses after DOD primes than after PD primes. In other words, adults showed evidence of abstract structural priming with low-frequency verbs; we calculated an effect size which confirmed that this priming effect was large

(Cohen's *d* = 0.93). There was no main effect of Prime bias, but there was an interaction between Prime Type and Prime Bias (β = -0.94, $\chi^2(1) = 3.83$, p = .05), suggesting that the magnitude of the priming effect varied according to the bias of the prime verb. To explore this interaction further, the mean proportion of DOD responses in each Prime Bias condition was calculated (Table 4.2).

Table 4.2 *Mean (SD) proportion of DODs after DOD and PD primes for both DOD- and PD-biased prime verbs.*

Prime verb bias	**Prime type**	
	DOD	**PD**
DOD-biased	0.36 (0.48)	0.12 (0.32)
PD-biased	0.25 (0.44)	0.17 (0.37)

Two separate models were fitted: one on a subset of the dataset that only included DOD-biased prime verbs, and the other on a subset that only included PD-biased prime verbs. Both models included a by-subject random slope for Prime Type. The results revealed a main of Prime Type for DOD-biased prime verbs (β = 1.46, $\chi^2(1) = 14$, p < .001). For PD-biased prime verbs, the effect of Prime Type was marginal (β = 0.53, $\chi^2(1) = 2.9$, p = .088). Thus, while adults showed evidence of abstract structural priming, this priming effect was stronger for DOD-biased verbs than for PD-biased verbs. Comparison of the effect sizes confirmed this interpretation; the effect size (Cohen's *d*) was substantially larger for DOD-biased prime verbs (1.40) than for PD-biased verbs (0.48).

4.3.2. Prime surprisal with low frequency verbs

The second aim of this study was to investigate whether adults are sensitive to prime surprisal with low-frequency verbs.

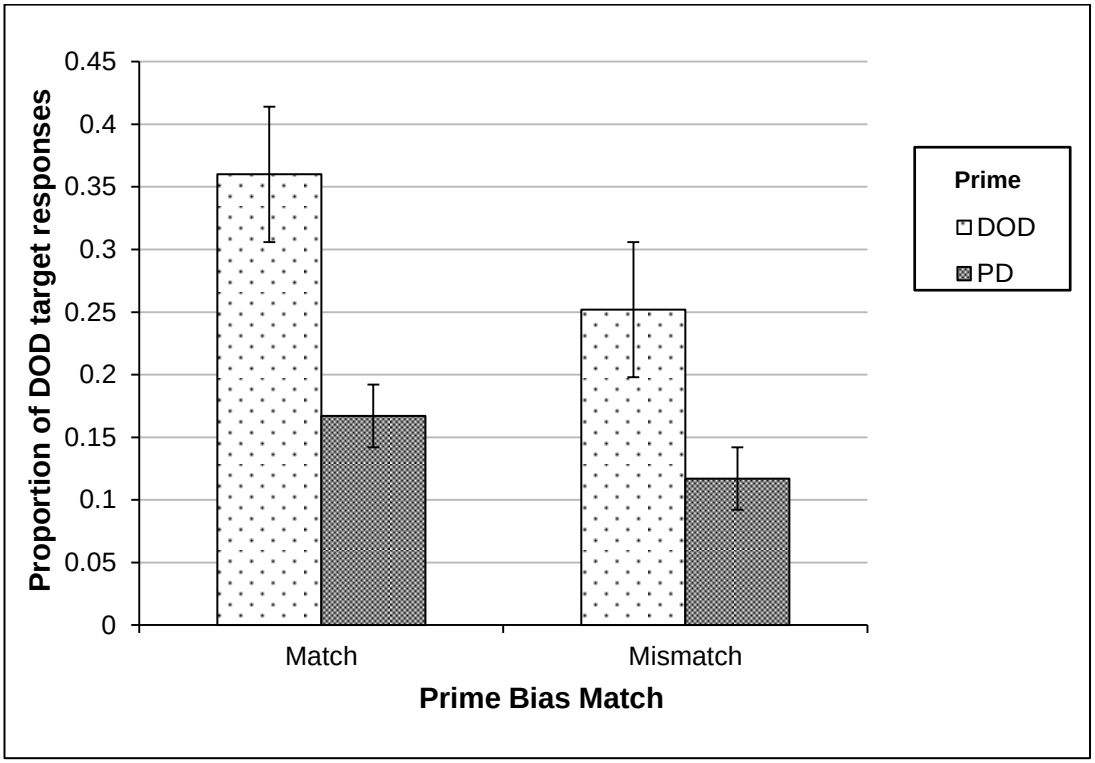

Figure 4.1 *Mean proportion of DOD responses when prime verb bias matched prime structure (Match), and when prime verb bias mismatched prime structure (Mismatch) (error bars indicate standard error)*

As in Study 3b in the last chapter, a Prime Bias Match variable was created. This allowed the assessment of whether the priming effect was larger when the prime verb bias mismatched the prime structure (e.g., “Mismatch” would be a PD-biased verb in a DOD structure) compared to when the prime verb bias matched the prime structure (e.g., “Match” would be a DOD-biased verb in a DOD structure). Figure 4.1 shows the mean proportion of DOD responses across both the Match and Mismatch condition. The model

included as fixed effects: a) Prime Type (DOD/PD), and b) Prime Bias Match (Match/Mismatch). It included by-subject random slopes for Prime Type, Prime Bias Match, and Prime Type crossed with Prime Bias Match. As before, there was a main effect of Prime Type (β = 1.00, $\chi^2(1) = 11.9$, $p < .001$). There was also a main effect of Prime Bias Match (β = -0.47, $\chi^2(1) = 4.08$, $p < .05$), which shows that more DOD responses were produced when prime structure and prime verb bias were matched. Importantly though, there was no interaction between Prime type and Prime Bias Match, indicating that the priming effect was of equal magnitude across both the Match and Mismatch condition (Cohen's *d*: Mismatch = 0.90 vs Match = 0.97). In other words, adults did not show evidence of prime surprisal with low-frequency verbs.

4.3.3. Summary of results

Adults were primed by dative sentences with low-frequency biased verbs, and the bias of the prime verb influenced the strength of the priming effect; priming was comparatively weaker for PD-biased prime verbs than for DOD-biased verbs. Overall, adults were not sensitive to verb-structure mismatches with low-frequency verbs. That is, they were not primed more strongly by sentences in which prime verb bias and prime structure were mismatched.

4.4. Study 4a: Discussion

The current study explored how adults' knowledge about verbs is linked to their knowledge of syntactic structure. To do this, we investigated the impact of two lexical effects, verb frequency and verb bias, on adults' responses in a

structural priming task. First, we assessed whether adults show evidence of abstract structural priming with low-frequency DOD- and PD-biased verbs. Then, we investigated whether adults are sensitive to verb-structure mismatches (prime surprisal) with low-frequency DOD- and PD-biased verbs.

The first aim was to examine whether adults show evidence of structural priming with low-frequency verbs. In order to test this, adults heard and produced prime sentences with low-frequency DOD- and PD-biased verbs, before producing target descriptions with low-frequency equi-biased verbs. As predicted, adults showed evidence of abstract structural priming; they were more likely to produce a DOD response (e.g., *The librarian faxed the boy a letter*) after a DOD prime (e.g., *The teacher awarded the girl a prize*), than after a PD prime (e.g., *The librarian faxed a letter to the boy)*. The size of the priming effect was also large (Cohen's d = 0.93).

An additional finding was an asymmetry in the structural priming effect; priming was substantially stronger for DOD-biased verbs than for PD-biased verbs. So, adults were more strongly primed by sentences like *The teacher awarded the girl a prize*, than *The boy flung the squirrel an acorn*. One possible explanation for this is that there are differences in the way in which DOD- and PD-biased verbs are linked to adult syntactic representations of the dative structure. On an account in which verb-structure links are developed via means of a frequency-based mechanism (like that instantiated in the Dual-path model; Chang, Dell, & Bock, 2006), verbs that are weakly linked to syntactic structure are more susceptible to structural priming effects (prime surprisal). Given that the dative structure permits far fewer verbs in the DOD structure than it does in the PD structure

(Ambridge, Pine, Rowland, Freudenthal, & Chang, 2014), we might expect DOD-biased verbs to be less frequent than PD-biased verbs, and, as a result, for adults to have less experience with them. If this is the case, then the observation of stronger priming effects for DOD-biased verbs might be because adults have weaker links between these verbs and their representation of the dative.

The second aim was to investigate whether adults are sensitive to prime surprisal with sentences containing low-frequency verbs. In the previous study (Study 3b), which tested both children and adults, prime surprisal was strongest in the children and decreased over the course of development, with the effect being only marginal in the adults. In chapter 3, we suggested that this was because the rate of learning early on is high, but then gradually slows with age. In terms of a model in which learning is error-driven (e.g., Chang et al., 2006), this means that early verb biases are affected more substantially by the prime structure than later verb biases. This can explain why adults are less sensitive than children to prime surprisal: they have had time over development to accumulate evidence for their biases, and the biases that they have acquired are, by this point, less susceptible to change.

An alternative interpretation of these findings, however, is that the adults in study 3b were simply not surprised by the prime sentences presented to them because they included dative verbs heard too often in both structures for them to realistically be unexpected. The current study addressed this by investigating whether adults are sensitive to prime sentences containing verb-structure mismatches with low-frequency verbs. It

was expected that adults would be more strongly primed in the mismatch condition, and that this effect would be larger than the one found in the previous study (study 3b) because the sentences in the current study used low-frequency verbs and might be considered more surprising. However, the results revealed that adults did not show evidence of prime surprisal; they were primed equally as often when the prime verb bias and its structure matched as when it mismatched (in fact the priming effect was slightly, though not significantly, smaller in the mismatch condition).

This result reinforces the conclusion in chapter 3 that prime surprisal effects are stronger in children than adults. However, the lack of any prime surprisal effect at all is not easily explained by the Dual-path model which predicts that unexpected primes should boost the priming effect. One possible explanation, however, is that the verbs in the task may have been so infrequent in the input, that adults had not accumulated enough knowledge about their biases to be surprised by verb-structure mismatches. A speaker must have experienced a verb in a particular syntactic structure (e.g., the DOD structure) a sufficient number of times compared to an alternate one (e.g., the PD structure) before they can develop verb biases. Given that adults will have had few opportunities to experience low-frequency alternating verbs in their structures, it is likely that the biases that they form for these verbs will be weaker in comparison to the biases of verbs that are highly frequent. In other words, it may be that adults were not more surprised to hear low-frequency verbs in one structure over another because their knowledge about these verbs' argument structure preferences was poorly-developed.

Another possibility, however, is that the adults were not surprised by sentences with verb-structure mismatches because they found these sentences more difficult to understand, or even ungrammatical. The verbs used in the task were ones chosen specifically because they are not frequent in written and spoken speech. Thus, it is possible that inexperience with these verbs combined with mismatches in verb-structure preferences worked to make these sentences sound strange (e.g., mismatched sentences like *The soldier lobbed the girl a bomb* are less typical than *The chef gave a meal to the doctor*). While connectionist models of sentence processing like the Dual-path model might predict that these types of sentences should produce large priming effects (because they are unexpected), it could be that these types of sentences are more difficult to interpret, and, if considered ungrammatical, might not even activate the representation for the dative structure. This could explain both why we find weaker priming in study 4a than study 3b, and why priming in the Mismatch condition was not significantly larger than in the Match condition. One way of addressing this would be to assess how acceptable the prime sentences with verb-structure mismatches used in this study are rated by adults. This was the aim of the next study.

4.5. Study 4b: Introduction

A number of studies have shown that the complexity of sentences influences how easy it is for adults to interpret them. For example, adults take longer to read sentences like, *The engineer examined by the doctor had a large mole,* than they do to read sentences like, *The engineer examined the license in*

the doctor's office (Traxler & Tooley, 2008), and when adults are asked to read sentences containing syntactic and semantic anomalies, this elicits event-related potentials (ERP) not observed when reading control sentences (Kutas & Hillyard, 1984; Osterhout, Allen, McLaughlin, & Inoue, 2002). It has also been suggested that language processing is sometimes shallow, and that listeners sometimes use heuristics like plausibility to interpret difficult sentences because this method is faster than performing a syntactic analysis (Ferreira, 2003). For example, Ferreira found that adults who heard grammatical but implausible passive sentences like, *The dog was bitten by the man*, tended to report that they had heard, *The man was bitten by the dog* – the more plausible interpretation – even though sentences were presented clearly, and there was no limit on how long participants had to respond. Ferreira, Bailey, and Ferraro (2002) suggest that by performing this type of shallow processing, listeners can create "good-enough" representations: representations that are not necessarily detailed or accurate, but are suitable for the needs of the task. Taken together, the literature suggests that adults have difficulty parsing sentences that are ambiguous, and that even when these sentences are completely grammatical they may resort to methods other than syntactic analysis to process them.

In the previous study, we found that adults were primed by sentences containing low frequency verbs, but that they were not sensitive to verb-structure mismatches (prime surprisal). Although one possibility is that they may not have accumulated enough evidence about the biases of these verbs for this to affect priming, another is that the sentences containing verb-

structure mismatches with low-frequency verbs could be difficult to parse. This could explain why we found no prime surprisal effects at all.

To test this, we asked adults to rate how acceptable they find the prime sentences in the previous study. If adults rate the mismatched sentences as less acceptable than the matched sentences, this might suggest that these sentences are difficult to parse (or even seen as ungrammatical) and could explain why participants in study 4a were not more strongly primed by these sentences. Further still, obtaining these ratings will allow us to assess whether the acceptability ratings of the prime sentences correlates with size of the priming effect reported in the previous study (study 4a).

4.5.1. The current study

The current study used a graded judgement paradigm to obtain acceptability ratings from adults for the prime sentences used in the previous study (study 4a). Our first aim was to investigate how acceptable adults found the sentences. In particular, we were interested to learn if they would rate sentences in which prime verb bias and structure are mismatched differently from sentences in which prime verb bias and structure are matched. Our second aim was to investigate whether these ratings were associated with the size of the structural priming effects found in study 4a. If adults perform shallow processing, and not full syntactic analysis for sentences that are difficult to understand, we might expect those sentences that are rated as least acceptable to also be those that are associated with the smallest structural priming effects.

To obtain the ratings, we used a graded judgment paradigm that is typically used to assess grammaticality. Although it has been argued that metalinguistic judgments are not entirely comparable to linguistic competence (since making a judgment is a controlled process, whereas language production and comprehension is more automatic; Ryan & Ledger, 1984), this method has been successfully used to test both children and adults and is accepted by many (see Ambridge, Pine, Rowland, & Young, 2008) to be an effective measure of grammatical acceptability.

4.6. Study 4b: Method

4.6.1. Overview

Adults took part in a graded judgement task in which they rated the acceptability of dative, figure-locative, and ground-locative sentences containing low-frequency verbs. The grammatical and ungrammatical figure-locative and ground-locative sentences were included for use as fillers. The dative sentences in the task were the same as those prime sentences presented in the structural priming task in study 4a, and were all grammatical.

4.6.2. Participants

Forty-three monolingual English-speaking adults were recruited from the University of Liverpool student participation pool. Participants were tested in groups of five in the language development laboratory at the University of Liverpool, and were different to those who took part in Study 4a.

4.6.3. Design and Materials

4.6.3.1. Design

The study used a 2 x 2 design. The two within-subjects variables were Sentence Type (DOD and PD), and Verb Bias (DOD- and PD-biased). The dependent variable for the descriptive analysis was the mean acceptability rating for each sentence. For the inferential analyses, the dependent variable was the rating for each sentence (which could range from 1 to 5).

4.6.3.2. Sentence stimuli

The task included a total of 48 sentences of which 24 were experimental. The remaining 24 sentences acted as fillers. The experimental sentences were the same dative sentences that were presented to the participants who took part in study 4a. Thus, 12 of these dative sentences were those in which prime verb bias and structure were matched (e.g., DOD-biased verb in DOD structure), and 12 of these were those in which prime verb bias and structure were mismatched (e.g., DOD-biased verb in PD structure). The filler items were a mixture of figure- and ground-locatives and were chosen because they have similar grammaticality ratings to the experimental sentences (ratings taken from Bidgood, Ambridge, Pine, & Rowland, 2014). The sentences were semi-randomized.

4.6.3.3. Rating scale

The five-point rating scale (see figure 4.2) for acceptability was one that has been successfully used with adults in other studies (e.g., Ambridge et al., 2012). The scale consists of five faces that change expression progressively

(where a sad face is equivalent to ‘really bad; something that I would never say’, and happy is equivalent to ‘perfect; something that I would say’). Each participant was given five sheets of A4 paper on which were seven trial sentences, and 48 test sentences. Each sentence was presented above an image of the rating scale.

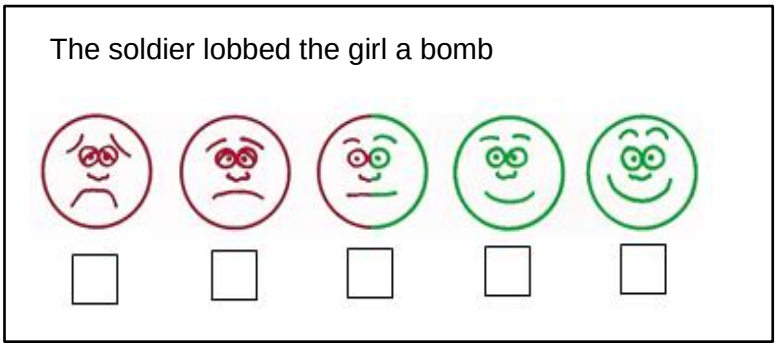

Figure 4.2 *Five-point rating scale for acceptability with trial sentence above as presented to participants*

4.6.4. Procedure

4.6.4.1. Practice session

Participants were tested in groups of five. Before they rated the sentences, they were given detailed instructions to explain the scale, including why a sentence might be rated as acceptable or unacceptable, as well as factors that should not be taken into account when rating a sentence (Schütze, 1996). To familiarize them with the process of using the scale and rating the sentences, participants took part in a practice session in which they observed and rated trial sentences that were different to the ones in the real test session (see Table 4.3).

Table 4.3 *Sentences presented to participants during the practice session*

Trial	Sentence type	Sentence	Completed by	Rating
a	passive	The queen was impressed by the maid	Experimenter	5
b	ground-locative	The boy nailed the wall with posters	Experimenter	1
c	passive	The city was surrounded by hills	Participant	5
d	ground-locative	The policeman spilt the rug with juice	Participant	1
e	active	The man tumbled the books off the table	Experimenter	3
f	figure-locative	The teacher filled paper into the box	Experimenter	2
g	figure-locative	The sailor covered salt onto his dinner	Experimenter	2

The experimenter rated the first two sentences as a demonstration of how to use the scale. Participants were then asked to rate the next two sentences in a similar way to that completed by the experimenter, receiving help from the experimenter should they be seen to using the scale incorrectly. The participants were told that a sentence should be judged as 'perfect' (the happiest face; equivalent to five) if they though that the sentence sounded perfectly fine and that it was something that they would probably say; a sentence should be judged as 'quite good' (the next happy face; equivalent to number four) if they thought that the sentence was not completely perfect, but was still fairly good. If participants thought a sentence was neither completely acceptable nor unacceptable, then they were instructed to rate this as 'neutral' (the middle face; equivalent to number three). Sentences were to be rated as 'not great' (the second sad face; equivalent to number two) if the sentence sounded quite strange and participants thought that would probably not ever say it. Finally, participants were told that sentences that sounded awful and were ones that think that thought would never be produced, were to be rated as 'really bad' (the saddest face; equivalent to number one). The aim of the training was to eliminate any participants who

demonstrated inability to correctly use the rating scale. However all participants were able to satisfactorily use the scale.

4.6.4.2. Test session

Participants were informed that the experimenter would read a series of sentences aloud, giving them only a few seconds to rate each one before moving on to the next. Limiting the amount of time possible to rate each sentence, means that participants are less likely to take pragmatic considerations and linguistic norms into account in their ratings (Schütze, 1996). Participants were instructed to read each sentence silently while listening to it being read by the experimenter, and then to rate each one by marking a tick in the box under the face on the scale that corresponded with how acceptable they found that sentence.

4.7. Study 4b: Results

The current study had two aims: 1) to investigate whether there was a difference in the way that adults rated the sentences in the task, and 2) to assess whether these ratings were associated with the size of the structural priming effects found in Study 4a.

A variety of linear mixed effect models were fitted to examine the data and were calculated using the *lmer* function of the *lme4* package in R (lme4: version 1.1-6; R Core Team, 2012). The dependent measure was the mean acceptability rating for each sentence; each sentence had a maximum possible rating of 5 (perfectly acceptable) and a minimum possible rating of 1 (completely unacceptable). Thus, each participant could score a maximum of

120, and a minimum of 24. Each participant rated 24 DOD and PD sentences with DOD- and PD-biased verbs; 12 of these sentences were those in which prime verb bias and structure were matched, and 12 were sentences in which prime verb bias and structure were mismatched. All factors were effect/sum coded (Wendorf, 2004). Model comparison was used to compute chi-square values.

4.7.1. Effect of sentence type and verb bias on acceptability rating

Our first aim was to investigate how acceptable adults found the sentences. To do this, we calculated the mean acceptability rating for each sentence type (DOD and PD) with DOD- and PD-biased verbs (see Table 4.4).

Table 4.4 *Mean (SD) acceptability ratings for DOD and PD sentences with DOD- and PD-biased verbs (maximum score = 5, minimum score = 1)*

Sentence Type	**Verb bias**	
	DOD-biased	**PD-biased**
DOD	4.47 (0.80)	3.35 (1.48)
PD	4.49 (0.75)	4.25 (0.96)

On average, participants rated sentences with PD-biased verbs (e.g., *lob*) lower than sentences with DOD-biased verbs (e.g., *award*), and sentences with a DOD a structure and a PD-biased verb were rated the least acceptable (e.g., *The soldier lobbed the girl a bomb*). However, on average, none of the four sentence types were rated as ungrammatical (scores below 3). The first model included as fixed effects: a) Sentence Type (DOD, PD),

and b) Verb Bias (DOD-biased verb, PD-biased verb). The model included by-subject random slopes for Sentence Type, Verb Bias, and Sentence Type crossed with Verb Bias. A main effect of Sentence Type (β = 0.88, $\chi^2(1) = 54.1$, $p < .001$) indicated that PD sentences were rated as more acceptable than DOD sentences (Cohen's $d = 0.41$), and a main effect of Verb Bias (β = 0.68, $\chi^2(1) = 51$, $p < .001$) showed that sentences with DOD-biased verbs were rated as more acceptable than sentences with PD-biased verbs (Cohen's $d = 0.39$). There was also a significant interaction between Sentence Type and Verb Bias (β = -0.46, $\chi^2(1) = 51$, $p < .001$), indicating that DOD sentences with PD-biased verbs were rated as the least acceptable (M = 3.35), followed by PD sentences with PD-biased verbs (M = 4.25), and then DOD sentences with DOD-biased verbs (M = 4.47). Interestingly, PD sentences with DOD-biased verbs were rated as most acceptable (M = 4.49). Thus, overall, mismatch sentences were not rated as less acceptable than match sentences.

4.7.3. The relationship between verb bias match and the size of the priming effect

The second aim was to examine whether the ratings of the sentences would correlate with the size of the priming effects reported in Study 4a. In particular, we were interested to see whether sentences rated as the least acceptable would be associated with smaller structural priming effects. To do this, we calculated two sets of difference scores: one for the acceptability ratings, and another for the priming task in Study 4a.

Table 4.5 *Mean (SD) ratings, mean (SD) DOD responses from Study 4a, and difference scores.*

	Acceptability task			**Priming task**		
	Rating		**Difference Score**	**DODs produced**		**Difference Score**
Verb	**DOD sentence**	**PD sentence**	**(DOD minus PD)**	**DOD prime**	**PD prime**	**(DOD minus PD)**
Award	4.72 (0.45)	4.66 (0.64)	0.06	0.29 (0.46)	0.15 (0.37)	0.13
Chuck	4.09 (0.80)	4.30 (0.86)	-0.21	0.45 (0.51)	0.05 (0.22)	0.40
Loan	4.00 (1.14)	4.21 (0.81)	-1.19	0.26 (0.45)	0.13 (0.34)	0.14
Promise	4.60 (0.68)	4.34 (0.92)	-0.23	0.33 (0.49)	0.17 (0.39)	0.16
Read	4.64 (0.67)	4.70 (0.51)	-1.74	0.30 (0.47)	0.00 (0.00)	0.30
Serve	4.76 (0.47)	4.74 (0.49)	0.02	0.55 (0.51)	0.18 (0.39)	0.36
Fling	2.89 (1.39)	4.09 (0.95)	-1.19	0.16 (0.37)	0.00 (0.00)	0.16
Issue	4.13 (1.13)	4.36 (0.79)	-0.23	0.33 (0.48)	0.33 (0.49)	0.00
Lob	2.11(1.15)	3.70 (1.20)	-1.60	0.50 (0.51)	0.32 (0.48)	0.18
Post	3.85 (1.14)	4.43 (0.87)	-0.57	0.12 (0.33)	0.20 (0.41)	-0.08
Write	4.72 (0.65)	4.79 (0.55)	-0.06	0.17 (0.39)	0.09 (0.29)	0.08
Kick	2.43 (1.26)	4.17 (0.99)	-1.74	0.20 (0.41)	0.09 (0.29)	0.11

To calculate the difference score for the acceptability ratings, we subtracted for each of the 12 verbs, the mean rating for PD sentences from the mean rating for DOD sentences. As a result the difference scores had a maximum of 4 and a minimum of -4. This gave us a score of each verb's preference for the DOD structure (a negative score indicates a preference for the DOD).[2] To calculate the difference score for the priming task, we subtracted the mean number of DOD responses after a PD prime from the mean number of DOD responses after a DOD prime (from study 4a) (see Table 4.5).

[2] Just as all structural priming effects in this thesis were analysed in terms of the number of DOD responses produced after DOD primes compared to after PD primes, the decision in this study to analyse each verb's preference for the DOD in the acceptability ratings was also random; we could equally have calculated each verb's preference for the PD structure.

A Pearson product-moment correlation coefficient was computed to assess the relationship between the ratings of the sentences and the amount of priming. The results revealed that acceptability of the sentences used in Study 4a was not correlated with the magnitude of priming; r = 0.19, n = 12, p = .55 (see Figure 4.3).

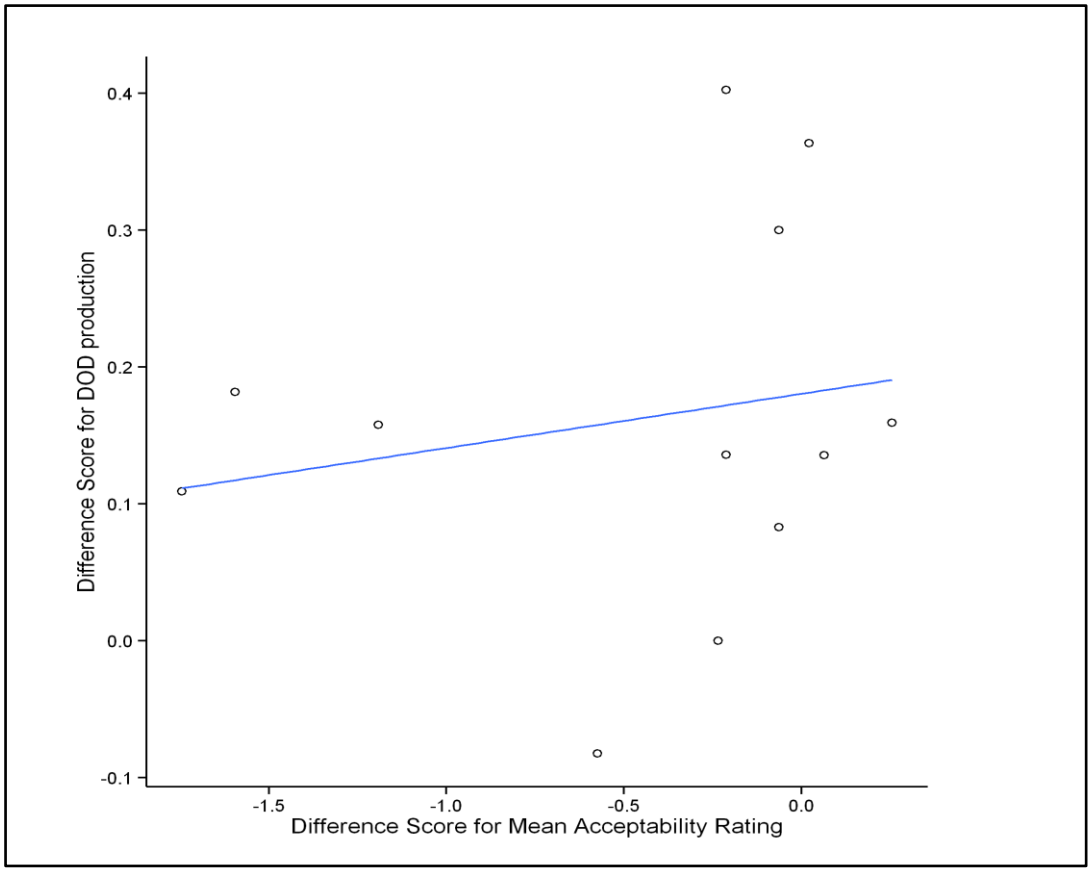

Figure 4.3 *Correlation between the rated acceptability of prime sentences and the magnitude of priming by verb*

In other words, in this case, how much adults were primed by the sentences in study 4a did not depend on how acceptable these prime sentences were deemed to be.

4.8. Study 4b: Discussion

Adults were asked to rate the acceptability of the prime sentences presented in the previous study (study 4a). The first aim was to investigate how acceptable adults found the sentences. In particular, we explored whether sentences in which verb bias and structure are mismatched were rated as less acceptable (and by inference, were more difficult to understand) than matched sentences. The second aim was to examine whether the ratings from this study correlated with the size of the priming effects observed in the previous study (study 4a).

With regards to testing the first aim, the results revealed that adults did not rate mismatched sentences consistently lower than matched sentences; some of the mismatched sentences were rated as less acceptable than some of the matched sentences, whilst some of the mismatched sentences were rated as more acceptable than some of the matched sentences.

An unexpected finding, however, was that adults rated the two types of mismatched sentences differently; DOD sentences with PD-biased verbs (e.g., *The boy flung the squirrel an acorn*) were rated as less acceptable than PD sentences with DOD-biased verbs (e.g., *The fire-fighter loaned a mop to the maid*). One way to explain this pattern of results is to consider these findings in the light of the nature of the dative structure – in particular, the frequency with which verbs appear in their argument structure preferences.

Although a number of semantic, morphological, and lexical constraints restrict the alternation of dative verbs between the DOD and PD structure (Harley, 2003; Krifka, 1999; Pinker, 1989), these constraints seem to impact

the DOD structure to a greater extent. That is, a larger number of verbs are prohibited from the DOD structure. For example, Ambridge, Pine, Rowland, Freudenthal, and Chang (2012) report that out of 156 non-alternating verbs, only 25 are grammatical in the DOD. Thus, in comparison to the PD structure, which appears with a greater number of verbs and post-verbal arguments, the DOD is fairly restricted. For example, in adults' speech to children, full noun phrases are likely to appear immediately after the verb in the PD structure but appear only occasionally in the DOD (Conwell, O'Donnell, & Snedeker, 2011). Thus, it is possible that the DOD is conceptualised as fairly inflexible, but the PD structure is viewed as relatively variable because it accepts a broad range of verbs. This could perhaps be why adults rated DOD-biased verbs in a PD structure (e.g. *The fire-fighter loaned a mop to the maid*) as more acceptable than PD-biased verbs in a DOD structure (e.g. *The boy flung the squirrel an acorn*); even though *loan* is not a verb that is heard often, adults' experience of the PD structure is that it is one that tends to accept a range of verbs and post-verbal arguments. In the same way, lack of experience with verbs like *fling* combined with the view that the DOD structure is more restrictive may have led adults to consider these sentences as less acceptable.

A key question then, is why might adults show such preferences? One possibility is that the asymmetry that we observed reflects a difference in the way in which knowledge about the properties of these structures is represented. This interpretation is further supported by the finding that PD sentences were rated as more acceptable than DOD sentences (regardless of the bias of the verb in that sentence). Further still, these differences do not

seem to be isolated to knowledge about syntactic structure: our findings also suggest that adults store information about the way in which verbs behave in these structures, with this knowledge influencing how they interpret (and perhaps process) syntactic information. Evidence for this comes from the finding that, irrespective of sentence structure, adults in our study rated sentences with DOD-biased verbs as more acceptable than sentences with PD-biased verbs.

If, as we suggest, the way in which adults represent the DOD structure is different from the way in which they represent the PD structure, we need to consider why this might be. Similarly, we must also consider how adults might come to have knowledge about how different verbs behave in these structures, and why this might influence the way in which they interpret language. One argument that we put forward to explain this is that adult speakers' linguistic representations are a product of their linguistic experiences. That is, throughout the acquisition process, children and adults pay attention to how certain structures are used and, in particular, when and how often certain verbs appear in these structures. We suggest that the accumulation of these experiences influences how adult syntactic representations develop, and, in turn, how adults use these representations to interpret syntactic information. Evidence to support this idea comes from work by Wonnacott, Newport, and Tanenhaus (2008) in which adults were exposed to an artificial language. In this language, verbs (e.g., *glim*) could appear in either of two constructions corresponding to a transitive event: Verb Noun1 Noun2 (e.g., *glim tombat blergen*) or Verb Noun2 Noun1 particle (e.g., *glim blergen tombat ka*). Some of the verbs appeared in both structures

equally as often (i.e., they were alternating), while others only ever appeared in one of the structures (i.e., they were non-alternating). Thus, biases were created for some of these verbs. When tested on production with this language, it was found that adults avoided overgeneralisation errors. That is, they tended only to produce verbs in the structures in which they had experienced them in the input. In addition, when errors were made, these were more often with low frequency verbs. When tested on comprehension, adults showed that they had learned enough about the verbs' syntactic preferences for it to influence their processing of sentences with these verbs. Taken together, these results suggest that speakers' experience of how structures are used and how verbs in these structure behave, affects the representations that they build, and, thus, the way in which they produce and interpret language. In terms of the current study then, we might propose that adults' preference for certain verb-structure combinations over others reflects how these structures have been experienced in the input.

The second aim of our study was to test whether adults' acceptability ratings correlated with the size of the priming effects in the previous study. We might expect that sentences rated the least acceptable are those that are more difficult to understand. Sentences that are difficult to understand might be subject to shallow processing (Ferreira et al., 2002), and so could be associated with small structural priming effects. We found that adults rated some of the mismatched sentences lower than some of the matched sentences, perhaps suggesting that these particular sentences were more difficult to parse. These ratings, however, were not associated with the size of the priming effect in study 4a. Thus, although the findings from this

chapter suggest that adults are sensitive to verbs' biases, they do not provide us with a clear explanation as to why adults did not show evidence of prime surprisal with sentences containing low-frequency verbs.

4.8.1. Summary and conclusion

To summarise, in this chapter we explored two reasons why adults might have shown weaker prime surprisal effects than adults in chapter 3. The findings from study 4a support previous evidence that adults possess abstract syntactic representations that they use to generalise across a range of verbs. However, the fact that adults were primed more strongly by DOD-biased verbs (study 4a), and that they rated sentences with DOD-biased verb more highly (study 4b), points to a difference in the way in which knowledge about DOD and PD verbs is stored and linked to syntactic representations. Adults were not sensitive to prime surprisal with low-frequency dative verbs, but they did rate (some) sentences with verb-structure mismatches as less acceptable than (some) sentences in which verb and structure were matched. This could be interpreted as evidence that sentences in which there is a discrepancy between verb bias and structure are difficult to parse. Nevertheless, we did not find any association between the ratings for mismatched sentences and the magnitude of the priming effect. Thus, the more plausible explanation for the absence of prime surprisal in adults is that they had not yet gathered enough evidence about the verbs' argument-structure preferences to find them unexpected in either structure.

One, perhaps, more effective way to explore how adults' knowledge of syntax is linked to their knowledge about how verbs behave in particular structures is to investigate whether they show prime surprisal with sentences containing non-alternating dative verbs. Since non-alternating verbs appear frequently in one structure, but rarely (if ever) in another, adults should find ungrammatical sentences with these verbs unexpected. The next chapter reports the findings of two structural priming tasks that tested whether adults show evidence of abstract structural priming and prime surprisal with ungrammatical and grammatical dative sentences.

Chapter 5

Are adults sensitive to prime surprisal with non-alternating dative verbs? Evidence from the structural priming paradigm

5.7. Study 5b: Discussion

5.7.1. Explaining the lack of priming with grammatical primes in Study 5a

5.7.2. Explaining the lack of priming with ungrammatical primes in Study 5a

5.8. Study 5b: Conclusion

Chapter 5: Are adults sensitive to prime surprisal with non-alternating dative verbs? Evidence from the structural priming paradigm

5.1. Study 5a: Introduction

In chapter 3 (study 3b), we investigated when and how verb-structure links are developed by using structural priming to test whether children (as young as three) and adults are sensitive to verb-structure mismatches (prime surprisal). We found that children showed evidence of prime surprisal, but that this effect was only marginal in adults. Although this result was unexpected - because significant prime surprisal effects in adults have been demonstrated in other work (e.g., Bernolet & Hartsuiker, 2010; Chang, Dell, & Bock, 2006; Jaeger & Snider, 2013), this finding is also interesting because it might indicate that the strength of syntactic representations and verb-structure links changes across development, and that these changes are a consequence of the different knowledge that children and adults bring to the task. Thus, our findings could have theoretical implications for our current understanding of syntactic development.

In chapter 4, we considered alternative explanations for this developmental pattern. It could be that, even though the verbs used in study 3b were biased towards either the DOD or PD structure, adults were too familiar with them in both structures to find them unexpected in either. So, we tested this idea in chapter 4 by investigating whether adults show prime surprisal with sentences containing low-frequency verbs (study 4a). Whilst we found that adults were primed by sentences containing low-frequency

verbs, they were not more strongly primed when the prime verb's bias mismatched the structure in which it appeared. So, again, adults did not show evidence of prime surprisal. One possible explanation for this finding, however, is that because the verbs were so infrequent in the input, adults may not have encountered them often enough to develop knowledge about their argument-structure preferences. For example, if *lob* (which is PD-biased) is not heard often, then hearing it in a DOD structure might not be that unexpected.

The aim of the current chapter was to explore this idea further. We tested whether adults are more strongly primed by verbs presented in an ungrammatical structure (i.e., a structure in which these verbs never appear). Specifically, we presented adults with prime sentences containing non-alternating dative verbs. Non-alternating verbs are the ultimate biased verbs because they are only grammatical in one of two alternating structures, usually for semantic, lexical, or morphological reasons (Harley, 2003; Krifka, 1999; Pinker, 1989). This means that they are highly frequent in one structure, but are rarely (if ever) experienced in the other. For example, although the verb *give* can alternate between the PD and DOD structure (e.g., *Joss is giving the football to his friend/Joss is giving his friend the football*), the verb *donate* is only permitted in the PD structure (e.g., *Joss is donating the football to his friend the football/*Joss is donating his friend the football*). If we consider structural priming in terms of error-based learning, in which stronger priming effects are yielded for unexpected sentences (Chang, Dell, & Bock, 2006), we might predict adults to be more strongly primed by sentences in which non-alternating verbs are presented in the dispreferred

(ungrammatical) structure because this is unexpected. Thus, exploiting the non-alternating property of these verbs could, perhaps, be a more effective way of investigating whether adults are sensitive to prime surprisal.

One potential issue, however, is that ungrammatical sentences might not even activate the appropriate representations for the DOD and PD structure, in which case, presentation of these sentences might not yield any structural priming effects at all. Currently, the available evidence on priming with ungrammatical forms is limited – although one recent study by Ivanova, Pickering, McLean, Costa, and Branigan (2012) has suggested that adults can be primed with these types of sentences. In their task, adults were presented with DOD and PD prime sentences. In some conditions, the prime verbs that appeared in these structures were alternating, and thus, were grammatical in both the DOD and PD structure (e.g., *give*). In other conditions, however, the prime verbs were non-alternating (e.g., *donate*); they were only grammatical in the PD structure (e.g., grammatical: *The waitress donates the book to the monk;* ungrammatical*: The waitress donates the monk the book*). Target verbs were also non-alternating PD-only verbs, and so producing a DOD target description with these verbs would be ungrammatical. Ivanova et al.'s principle findings were that adults showed no evidence of priming when the prime verb was alternating (i.e., the sentence was grammatical; *The waitress gives the monk the book*) and the target verb was non-alternating (e.g., *donate*). However, they were primed to produce ungrammatical target responses when the prime sentence was ungrammatical (e.g., *The waitress donates the monk the book*) and the target verb was non-alternating, as long as the prime and target verb were

the same (e.g., priming with *donate-donate,* but not *donate-display*). They were also primed to produce grammatical target responses when the prime sentence was ungrammatical and the target verb was alternating (e.g., *show*). These findings indicate that even when there is conflict between the DOD structure and the identity of the prime verb, this still results in the activation of the appropriate DOD representation. Thus, it appears that the structure of the prime is important for priming. However, these results also suggest that when presented with ungrammatical DOD sentences, activation of the DOD representation relies on lexical overlap when the target response is also ungrammatical.

Ivanova et al. (2012) have revealed that it is possible to prime adults with non-alternating verbs in ungrammatical sentences. Thus, we decided to test our hypothesis: that adults might be more surprised by verb-structure mismatches with prime verbs that grammatical (frequent) in one structure but ungrammatical (infrequent) in another. We did note, however, that the literature on priming with ungrammatical forms is small; Ivanova et al. are the only ones, as far as we are aware, to have found such priming effects with these types of sentences. Since it is entirely plausible that ungrammatical sentences do not activate the relevant representations, a secondary aim was to see if adults even show evidence of priming with ungrammatical primes.

5.1.1. The current study

The current study investigated how adults' knowledge of syntax is linked to their knowledge about how verbs behave in particular structures. Our first

aim was to explore whether adults are sensitive to prime surprisal with ungrammatical primes containing non-alternating DOD-only and PD-only verbs. These verbs are highly frequent in one structure, but are rarely (if ever) experienced in the other. Adults might, therefore, find sentences in which there is conflict between the prime structure and the prime verb's identity (i.e., ungrammatical sentences: DOD-only verb in a PD structure; PD-only in a DOD structure) unexpected. As such, we may see stronger priming after ungrammatical primes than after grammatical primes because the presentation of an ungrammatical prime might result in larger weight changes between verbs and representations of the prime structure. Another possibility, however, is that the presentation of ungrammatical primes will activate the relevant dative representation regardless of the verb in that prime. If so, we might find that adults are primed just as much by ungrammatical sentences as they are by grammatical ones.

Our second aim was to investigate whether adults show evidence of abstract structural priming with ungrammatical primes. If, as Ivanova et al. (2012) suggest, ungrammatical primes activate the appropriate syntactic representation, then adults should echo the syntax of the prime structure in their target responses when this target verb is alternating. If however, ungrammatical forms do not activate the appropriate syntactic representations, then we might not see evidence of structural priming at all.

5.2. Study 5a: Method

5.2.1. Participants

A total of 62 monolingual English-speaking adults (46 females) were tested. These participants were recruited from the University of Liverpool student participation pool and were tested individually in the language development laboratory at the University of Liverpool.

5.2.2. Design and Materials

5.2.2.1. Design

The study used a 2 x 2 design. The two within-subjects variables were Prime Type (DOD and PD), and Prime Bias (DOD-only and PD-only)[1]. The dependent variable for the descriptive analysis was the proportion of dative responses that were DODs (a ratio of DOD responses over the sum of DOD and PD responses). For the inferential analyses, the dependent variable was binary (1 = DOD, 0 = PD).

5.2.2.2. Visual stimuli

Ninety-six still cartoon images were designed and presented in E-Prime 2.0. The cartoons included two pairs of donor and recipient characters that are familiar to British adults and have proper noun names: *Marge and Homer*, and *Bart and Lisa* (from The Simpsons). The remaining donor and recipient characters were referred to with determiner + noun NPs (e.g., *the boy, the waitress, the builder).* Objects were referred to with both indefinite determiner

[1] In our analyses we created an additional variable called Grammaticality to allow us to compare priming for grammatical and ungrammatical prime sentences. Details of how this variable was created can be found in the Results section.

+ noun NPs (e.g., *a cake, a tyre, a chocolate bar*) and definite determiner + noun NPs (e.g., the secret, the news, the medicine).

Forty-eight cartoons depicted transfer actions that can be described with dative sentences. Forty-eight cartoons were used as fillers and depicted non-causal actions that can be described with intransitive sentences. Eight of the images that were used as fillers were also used in a practice session. Each prime picture was always paired with a target picture that included different characters from those in the prime. As in the previous studies, images depicted the direction of motion of transfer actions equally often from right-to-left and from left-to-right to control for the possibility that direction of transfer could influence structure choice.

5.2.2.3. Sentence stimuli

The 12 prime verbs used were selected because they have been reported as being grammatical in only one of the two datives (Levin, 1993). Seven of these verbs are permitted only in the PD structure (PD-only: *pull, carry, lift, shout, whisper, explain*, *announce)*, and five are allowed only in the DOD structure (DOD-only: *bet, save, refuse, cost, deny*).[2] Thus, in contrast to Ivanova et al. (2012) who only tested adults with PD-only verbs, the current study included both PD-only and DOD-only verbs. All prime verbs were paired with six target verbs: *throw, feed, pass, lend, toss*, and *owe*. To take into account the potential influence of verb-structure preferences, these target verbs were chosen because they display no preference for one structure over another. In doing so this increased the likelihood that any

[2] Sentences containing these DOD- and PD-only verbs were also rated by adults as ungrammatical in the PD and DOD structure, respectively (Ambridge, Pine, Rowland, Freudenthal, and Chang, 2012)

effects observed would be isolated to an effect of the prime verb and structure.

Forty-eight different dative sentences and 24 verb stems (e.g., *The man tossed…*) were created to describe the 48 cartoons depicting transfer actions. Twenty-four of these cartoons (two cartoons per verb) were described by 24 prime sentences using a DOD structure (e.g., *The girl denied the soldier a meal*). A further 24 prime sentences described the same cartoons but used the PD structure (e.g., *The girl denied a meal to the soldier*). Forty-eight target verb-stems (four verb-stems for each verb) were created, in addition to 48 filler sentences which used an intransitive structure (e.g., *The man was swimming)*. Each verb was presented twice per participant: once each in a DOD structure and PD structure. Each participant was exposed to 24 prime-target pairs, interspersed with 24 filler-filler pairs. No participant was asked to produce the same prime sentence twice. Prime verbs were always paired with different target verbs. To avoid lexical overlap, characters in prime sentences were always paired with target sentences that included different characters.

To control for sentence-specific preferences, six counterbalance groups were created to ensure that: 1) sentences that appeared as a DOD prime in one counterbalance group appeared as a PD prime in another, and vice versa; and 2) each prime verb was paired with the six target verbs equally as often. All sentences across counterbalanced groups were presented semi-randomly. This ensured that: 1) participants could not predict the structure of consecutive prime sentences, 2) characters appearing in a filler-filler pair would not have appeared in the preceding target sentence or

in the following prime sentence, and 3) consecutive prime sentences did not contain the same prime verb.

5.2.3. Procedure

The procedure was identical to that used in Study 4a, except that this time, participants did not take part in a memory task.

5.3. Study 5a: Results

The aims of the present study were to investigate: 1) whether adults show evidence of prime surprisal with ungrammatical prime sentences containing non-alternating DOD- and PD-only verbs, and 2) whether adults show evidence of structural priming with these ungrammatical prime sentences.

Logistic mixed effect models were fitted to examine the data (Baayen, Davidson, & Bates, 2008; Jaeger, 2008), and were calculated using the *glmer* function of the *lme4* package in R (lme4: version 1.1-6; R Core Team, 2012). The dependent measure was the structure produced by the participant (DOD = 1, PD = 0). All factors were effect/sum coded (Wendorf, 2004). Model comparison was used to compute chi-square and p-values.

5.3.1. Structural priming with non-alternating dative prime verbs

We first tested whether adults show evidence of structural priming with ungrammatical prime sentences containing DOD- and PD-only verbs. We calculated the percentage of DOD responses produced after DOD and PD

primes for DOD- and PD-only verbs (see Table 5.1)[3]; grammatical sentences are those in which prime type and prime bias are matched (e.g., DOD-only verb in a DOD prime/PD-only verb in a PD prime), and ungrammatical sentences are those where prime type and prime bias are mismatched (e.g., DOD-only verb in a PD prime/PD-only verb in a DOD prime).

Table 5.1 *Percentage of DOD responses after DOD and PD primes (sentences with matching prime bias and prime type are grammatical, sentences with mismatching prime bias and prime type are ungrammatical)*

Prime Type	**Prime Bias**	
	DOD-only	**PD-only**
DOD	61.40	62.24
PD	62.32	61.07

Descriptive statistics revealed that adults produced a similar percentage of DOD responses after DOD primes as they did after PD primes. The first model included as fixed effects: a) Prime Type (DOD/PD), and b) Prime Bias (DOD-only verb/PD-only verb). The model included by-subject random slopes for Prime Type, Prime Bias and Prime Type crossed with Prime Bias. The results revealed no main effect of Prime Type (β = 0.06, $\chi^2(1) = 0.01$, p = .926), which is unsurprising as the percentage of DODs produced after DOD and PD primes was virtually identical (confirmed by the very small effect size (Cohen's *d* = 0.02). There was also no effect of Prime Bias (β = 0.01, $\chi^2(1)$ 0.003, p = .95), which shows that adults produced as many DOD responses with DOD-only prime verbs as they did with PD-only prime verbs. Finally,

[3] The percentage of DOD responses was calculated over the dative responses only; responses coded as "Other" were not included.

there was no interaction between Prime Type and Prime Bias (β = 0.15, $\chi^2(1) = 0.38$, p = .54).

In sum, the results revealed that adults were not primed by ungrammatical sentences containing non-alternating dative prime verbs. At first, this might suggest that we are unable to test the first aim: whether adults are more strongly primed by ungrammatical sentences than by grammatical sentences. On closer inspection of the descriptive data, however, we noted that for grammatical sentences adults did produce more DOD responses after DOD primes than after PD primes. This pattern was not observed for ungrammatical sentences, where they actually produced fewer DOD responses after DOD primes than after PD primes (see Figure 5.1). So, these findings suggest that adults were (albeit not significantly) primed more strongly by grammatical sentences.

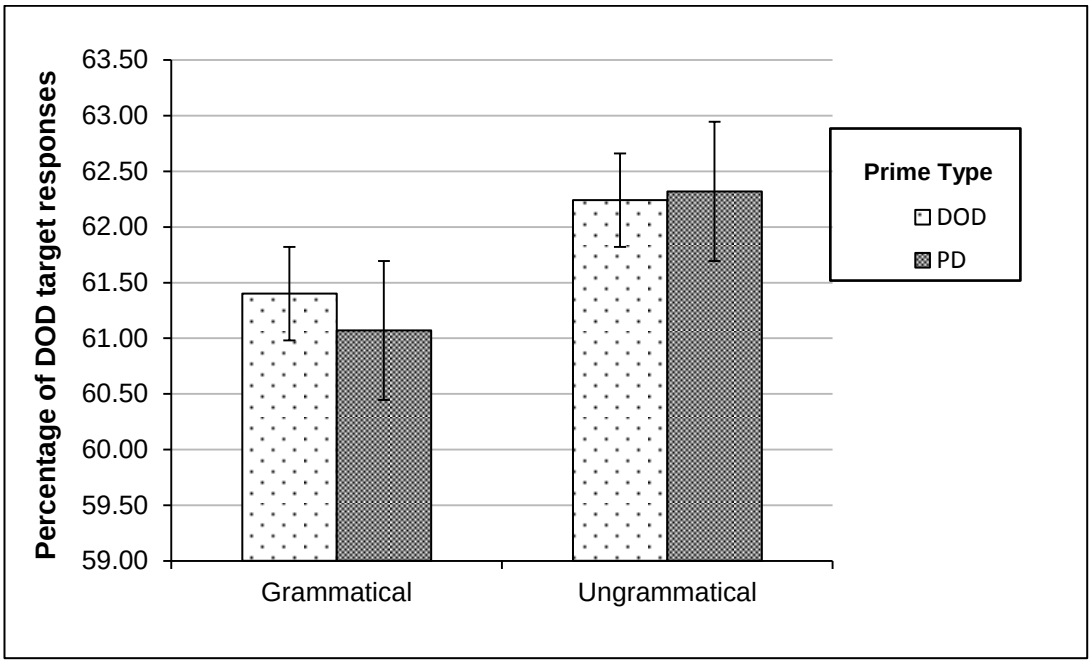

Figure 5.1 *Percentage of DOD responses after DOD and PD primes for grammatical and ungrammatical primes (error bars indicate standard error)*

To explore this further, we created a Grammaticality variable. This allowed the assessment of whether the priming effect was larger when the prime verb was grammatical in the prime structure (e.g., “Grammatical” would be a DOD-only verb in a DOD structure, or a PD-only verb in a PD structure) compared to when the prime verb was ungrammatical in the prime structure (e.g., “Ungrammatical” would be a PD-only verb in a DOD structure, or a DOD-only verb in a PD structure). The model included as fixed effects: a) Prime Type (DOD/PD), and b) Grammaticality (Grammatical/Ungrammatical). It included by-subject random slopes for Prime Type, Grammaticality, and Prime Type crossed with Grammaticality. As before, there was no main effect of Prime Type (β = 0.02, $\chi^2(1) = 0.03$, p = .85; Cohen’s *d* = 0.02). There was also no main effect of Grammaticality (β = 0.05, $\chi^2(1) = 0.13$, p = .72), and no interaction between Prime Type and Grammaticality (β = -0.001, $\chi^2(1) = 0$, p = .99). In other words, the size of the priming effect did not depend on the grammaticality of the prime sentence.

5.4. Study 5a: Discussion

The current study tested: 1) whether adults show evidence of prime surprisal with ungrammatical prime sentences containing non-alternating DOD- and PD-only verbs, and 2) whether adults show evidence of structural priming with these ungrammatical prime sentences. We found that adults did not show evidence of prime surprisal in that they were not more strongly primed by ungrammatical sentences. In fact, they were not primed by ungrammatical sentences at all in that they did not produce significantly more DOD responses after DOD primes than after PD primes with these sentences.

Instead, for ungrammatical sentences, they tended to produce more PD responses after DOD primes than after PD primes. The descriptive data did, however, show that adults were primed by grammatical sentences - although this effect did not reach significance.

Only one other study so far has examined whether adults are primed by ungrammatical sentences; Ivanova et al (2012) found that DOD sentences with PD-only verbs primed the production of DOD responses with alternating target verbs. This was interpreted as evidence that the presentation of an ungrammatical DOD utterance activates the DOD representation. That is, even when there is conflict between the DOD structure and the prime verb's identity, this still results in the activation of the appropriate DOD representation. Contrary to Ivanova et al., the findings from the current study showed that producing an ungrammatical DOD sentence (e.g., *The girl explained the boy the mistake*) did not make participants more likely to produce a DOD response with an alternating verb (e.g., *Homer fed Marge a lolly*).

In terms of our first aim, we considered that, if adults were primed by ungrammatical sentences, this effect might be larger than the priming effects observed with grammatical sentences. This is because adults might find sentences in which there is conflict between the prime structure and the prime verb's identity (i.e., ungrammatical sentences: DOD-only verb in a PD structure; PD-only in a DOD structure) more unexpected. An alternative suggestion was that ungrammatical sentences might prime just as much as grammatical ones because the presentation of an ungrammatical sentence may activate the appropriate dative representation irrespective of the verb in

that prime. Our findings, however, are not consistent with either of these proposals. Instead, they indicate that, for the adults in our study, the presentation of ungrammatical prime sentences did not activate the appropriate representations to produce structural priming effects.

One very unexpected finding was that adults did not even show significant evidence of structural priming with grammatical sentences. Although they did tend to produce more DOD responses after DOD primes than after PD primes for these sentences (which suggests that the presentation of grammatical, and not ungrammatical, DOD prime sentences is important for the activation of a DOD representation), this effect was non-significant. So, even when the prime verb's identity matched the structure in which it appeared, adults did not re-use the syntax of the prime in their target utterances.

The fact that adults did not show significant structural priming in this study with grammatical sentences is difficult to explain. Given that previous findings (this body of work included) have reported robust structural priming effects in adults, it would be unreasonable to interpret the absence of structural priming with grammatical forms in this study as evidence that adults are unable to use abstract knowledge of structure to generalise across sentences. We should, instead, attribute the absence of the priming effect to some feature of the task. For example, it could be that the presentation and production of ungrammatical forms acted as a 'red flag' to participants, alerting them to the incorrect verb-structure combinations. Twenty-nine per cent of the participants in Ivanova et al.'s (2012) study reported noticing mistakes in the ungrammatical prime sentences, and a further 14% reported

that these sentences were unnatural. It could be, therefore, that adults found the ungrammatical sentences in the current study difficult to understand. As discussed in the previous chapter, when faced with difficult sentences, adults might rely more on shallow processing to interpret meaning, and less on forming a thorough syntactic analysis (Ferreira, Bailey, & Ferraro, 2002). The adults in our study may have found the ungrammatical sentences difficult to understand, and this may have encouraged them to treat all of the sentences – even the grammatical ones, in this way. As such, they may only have formed representations that were "good enough" for the task (i.e., that allowed them to produce a description of a target image), but that were not detailed or accurate enough to enable them to echo the structure of the prime.

To explore this idea, the next study presented a different group of adults with grammatical sentences only, and these sentences included a selection of the non-alternating verbs presented to adults in study 5a. If the lack of a priming effect with grammatical sentences in the previous study was a consequence of encountering both ungrammatical and grammatical primes in the same task, then only presenting non-alternating verbs in their grammatical structure (e.g., DOD-only verb in DOD structure) and not in their ungrammatical structure (e.g., DOD-only in PD structure) should restore the structural priming effect with these sentences.

5.5. Study 5b: Method

5.5.1. Participants

A further 29 monolingual English-speaking adults (18 females) were tested. These participants were recruited from the University of Liverpool student participation pool and were tested individually in the language development laboratory at the University of Liverpool.

5.5.2. Design and Materials

5.5.2.1. Design

The study used a 5 x 2 design. The within-subjects variables were Prime Bias (DOD-biased, PD-biased, DOD-only, PD-only, and equi-biased,) and Prime Type (DOD and PD). The dependent variable was calculated as the proportion of DOD target responses produced (a ratio of DOD responses over the sum of DOD and PD responses).

5.5.2.2. Visual stimuli

Seventy-two still cartoon images were designed and presented in E-Prime 2.0. The cartoons included two pairs of donor and recipient characters that are familiar to British adults and have proper noun names: *Marge and Homer*, and *Bart and Lisa* (from The Simpsons). The remaining donor and recipient characters were referred to with determiner + noun NPs (e.g., *the boy, the waitress, the builder).* Objects were referred to with indefinite determiner + noun NPs (e.g., *a cake, a balloon, an apple*).

Thirty-six cartoons depicted transfer actions that can be described with dative sentences. Ten of these cartoons were exactly the same as those

seen by adults in the previous study (study 5a), whilst seven of these cartoons depicted the same images as in the last study but were paired with a different verb. For example, in study 5a, the image depicting a woman, a baby, and a banana was used to elicit a target response with the verb *feed* (e.g., *the woman fed a banana to the baby/the baby a banana*), but in the current study, this same image was used to elicit a target description with the verb *hand* (e.g., *the woman handed a banana to the baby/the baby a banana*). The remaining 19 images were ones that had not been seen by adults in the previous study[4].

Thirty-six cartoons were used as fillers and depicted non-causal actions that can be described with intransitive sentences. All of these cartoons were the same ones presented to adults in study 5a. Eight of the images that were used as fillers were also used in a practice session. Each prime picture was always paired with a target picture that included different characters from those in the prime. As in the previous studies, images depicted the direction of motion of transfer actions equally often from right-to-left and from left-to-right to control for the possibility that direction of transfer could influence structure choice.

5.5.2.3. Sentence stimuli

In order to investigate whether presenting adults with ungrammatical primes as well as grammatical primes within the same task contributed to the lack of structural priming in the previous study, it was important that, in the current

[4] It was necessary to include additional images because some of the verbs in this study were different to those used in Study 5a. Since these new verbs denoted different transfer events, they required new images. Sometimes, however, the depiction of the new transfer event was similar to the event in the previous study (e.g., the act of "feeding" and "handing" can be depicted in the same way). In such cases, these cartoons from the previous study were simply paired with the new, different verb.

study, adults were only presented with prime sentences in their grammatical forms. To allow comparisons between the previous task and the current one, we included six of study 5a's non-alternating verbs (three PD-only and three DOD-only). Since we were testing whether adults can be primed with these six verbs if they are presented in grammatical sentences, they were only ever presented in structures that made them grammatical. Thus, for these verbs, their bias always matched the structure in which they appeared (i.e., PD-only verbs only appeared in PD structures, and DOD-only verbs only appeared in DOD structures). To retain a similar format to the previous study, in which adult heard sentences where prime verbs both matched and mismatched the prime structure (i.e., grammatical and ungrammatical sentences), we decided to include a further six verbs with biases that mismatched the structure in which they appeared (e.g., DOD-biased verb in a PD structure). Essentially, these mismatched sentences correspond to the ungrammatical sentences in study 5a. An important difference though, was that these sentences were never ungrammatical because these six verbs, while biased towards either the DOD or PD, can alternate between both structures. We also included six equi-biased prime verbs. Since these verbs show no preference for either the DOD or PD structure, there should be no conflict between their identity and the structure in which they appear. Thus, sentences in which these verbs are presented can be considered "matched". In this way, the study used 12 prime verbs where prime bias and prime structure were always matched (six alternating [equi-biased] and six non-alternating [DOD- and PD-only]), and six prime verbs where prime bias and structure were mismatched.

Thus, 18 different prime verbs were selected for this task. Six of these were non-alternating verbs used in study 5a: *carry, whisper, explain* (all PD-only), and *bet, deny, cost* (all DOD-only). A further six of the verbs are alternating verbs that are biased towards one variant of the dative: *bring, sell, take* (all PD-biased), and *give, show, and offer* (all DOD-biased). The remaining six prime verbs are equi-biased: *throw, feed, pass, toss, fax, slip*. All prime verbs were paired with six equi-biased target verbs: *slide, send, hand, lend, flick*, and *owe*.

Eighteen different dative sentences and 18 verb stems (e.g., *The woman slid…*) were created to describe the 36 cartoons depicting transfer actions. Each cartoon was described by one prime sentence (i.e., one cartoon per verb). The three cartoons depicting actions with the equi-biased verbs *throw*, *pass*, and *fax* were always described by a prime sentence using a PD structure (e.g., *Bart threw a ball to Lisa)*. The three cartoons depicting actions with the equi-biased verbs *feed*, *toss*, and *slip* were always described by a prime sentence using a DOD structure (e.g., *The nurse fed the horse an apple)*. The three cartoons depicting actions with the PD-biased verbs *bring*, *sell*, and *take* were always described by a prime sentence using a DOD structure (e.g., *The queen brought the soldier a medal),* and so were mismatched. The three cartoons depicting actions with the DOD-biased verbs *give*, *show*, and *offer* were always described by a prime sentence using a PD structure (e.g., *The maid showed £10 to a policeman),* and so were mismatched. The three cartoons depicting actions with the DOD-only verbs *bet*, *deny*, and *cost* were always described using a DOD structure (e.g., *The girl denied the soldier a meal),* and so were always grammatical.

The three cartoons depicting actions with the PD-only verbs *carry*, *whisper*, and *explain* were always described using a PD structure (e.g., *The chef carried a meal to the doctor),* and so were always grammatical. Eighteen target verb-stems (three verb-stems for each target verb) were created, in addition to 36 filler sentences which used an intransitive structure (e.g., *The man was swimming)*.

Each verb was presented once per participant. Each participant was exposed to 18 prime-target pairs, interspersed with 18 filler-filler pairs. No participant was asked to produce the same prime sentence twice. Prime verbs were always paired with different target verbs. To avoid lexical overlap, characters in prime sentences were always paired with target sentences that included different characters. Six counterbalance groups were created for the same reasons as study 5a: to ensure that sentences that appeared as a DOD prime in one counterbalance group appeared as a PD prime in another, and vice versa, and that each prime verb was paired with the six target verbs equally as often.

5.5.3. Procedure

The procedure was identical to that used in study 5a.

5.6. Study 5b: Results

The aim of the present study was to investigate whether the absence of structural priming with grammatical forms in study 5a was a consequence of encountering both ungrammatical and grammatical prime sentences in the same task. To do this, the current work presented adults only with

grammatical prime sentences containing equi-biased, DOD- and PD-biased, and DOD- and PD-only verbs.

Logistic mixed effect models were fitted to examine the data. The dependent measure was the structure produced by the participant (DOD = 1, PD = 0). Model comparison was used to compute chi-square and p-values. We first calculated the percentage of DOD responses after DOD and PD primes.

Table 5.2 *Percentage of dative target responses that were DOD after DOD and PD primes*

Prime type	**Percentage of DOD responses**
DOD	49.36
PD	35.37

Table 5.2 shows that adults produced 14% more DOD targets after DOD primes than they did after PD primes. We fitted the data to a model that included Prime Type (DOD/PD) as a fixed effect, and by-subject random slopes for Prime Type. The results revealed a main effect of Prime Type (β = 0.79, $\chi^2(1) = 4.99$, $p < .05$; Cohen's $d = 0.28$), indicating that adults did indeed produce significantly more DOD responses after DOD primes than after PD primes. In other words, adults were primed by non-alternating dative verbs when these verbs were presented in an argument structure that made the prime sentence grammatical. This is contrary to our previous results (study 5a) where adults showed no significant evidence of structural priming

when adults were presented with these same non-alternating verbs in grammatical and ungrammatical structures.

To provide a more direct comparison between the findings from the current study and the previous one, we re-analysed the data from study 5a. This time, the model was fitted to a subset of the data from study 5a that only included the responses for the six non-alternating verbs that were tested in this study (*bet, deny, cost, explain, whisper, carry*). The model included Prime Type as a fixed effect (DOD/PD) with Prime Type as a by-subject random slope.

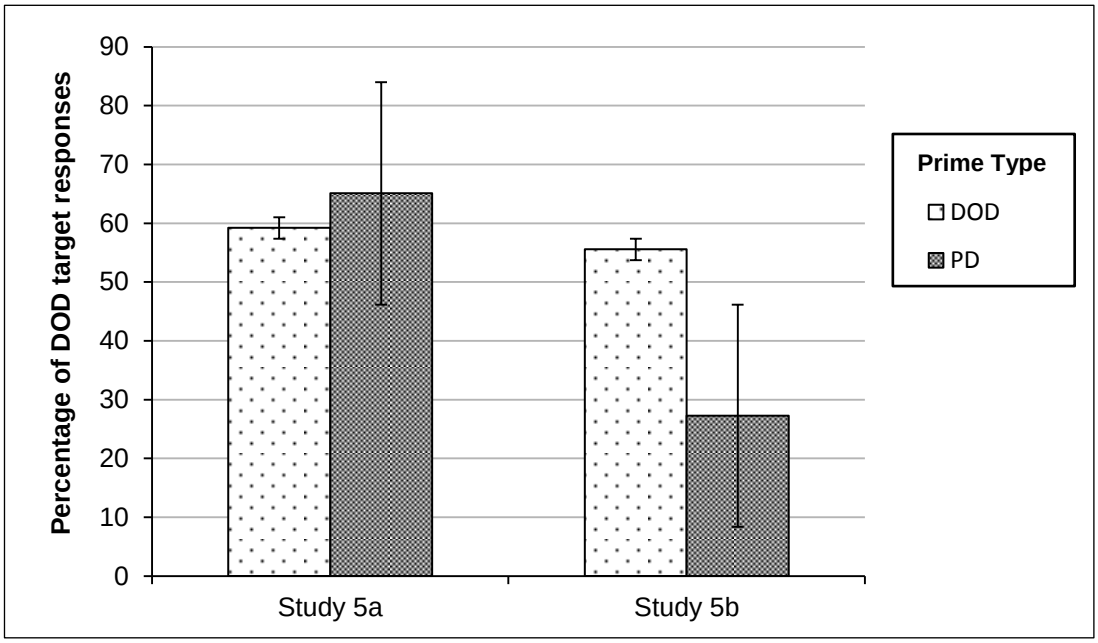

Figure 5.2 *Percentage of DOD responses after DOD and PD primes for DOD- and PD-only verbs presented in their grammatical forms for study 5a and study 5b (error bars indicate standard error)*

Given that the results from Study 5a revealed no evidence of structural priming, we were not surprised to find no effect of Prime Type (β = -0.30,

$\chi^2(1) = 2.56$, $p = .11$) for the six non-alternating verbs. Thus, our findings indicate that when adults encountered these six verbs in both grammatical and ungrammatical primes, they did not echo the syntax of the prime when producing their target response. In fact, even when we fitted an additional model to a subset of the data from Study 5a that only included responses when these six non-alternating verbs were presented in their grammatical structures, there was still no effect of Prime Type ($\beta = -0.34$, $\chi^2(1) = 1.66$, $p = .20$). In other words, even when there was no conflict between the prime verb and its structure, adults in study 5a still showed no evidence of structural priming with these verbs. In contrast, adults in the current study (study 5b) were primed by these types of sentences. The comparison between these two effects is shown clearly in Figure 5.2; the percentage of DOD responses after DOD primes compared to PD primes for these six verbs in their grammatical forms is much larger in the current study than in study 5a.

5.7. Study 5b: Discussion

Adults in the previous study, study 5a, were presented with both ungrammatical and grammatical prime sentences containing non-alternating dative verbs. They were not primed with ungrammatical sentences containing these verbs (e.g., DOD-only verb in a PD structure), and although they produced more DOD responses after DOD primes than after PD primes when presented with grammatical sentences containing these verbs (e.g., DOD-only verb in a DOD structure), this effect did not reach significance. In other words, they showed no priming irrespective of whether these verbs were grammatical or ungrammatical in their structures.

In study 5b we tested the idea that the absence of a priming effect with grammatical sentences is attributable to encountering both ungrammatical and grammatical primes in the same task. To test this, adults in the current study were only ever presented with prime sentences in which non-alternating verbs were grammatical in their structure (e.g., in this study the PD-only verb *explain* only ever appeared in a PD structure, whereas in study 5a it appeared in both the PD and DOD). We found that when they encountered only grammatical sentences with non-alternating verbs, they showed a significant tendency to re-use the syntactic structure of the prime. In comparison, when they were presented with both grammatical and ungrammatical sentences with these verbs in the same task, as in the previous study, study 5a, they showed no evidence of priming at all.

5.7.1. Explaining the lack of priming with grammatical primes in study 5a

The previous study (study 5a) revealed an unexpected finding: adults showed no evidence of structural priming when non-alternating verbs were presented in structures that made them grammatical. In the current study (study 5b), however, adults who were presented with grammatical sentences containing these same verbs did show evidence of structural priming. We suggest, therefore, that the presentation of ungrammatical prime sentences alerted the adults to the fact that the task was interested in testing the types of sentences that they produced. For example, the verb, *explain* is not typically expressed in a DOD structure because this is ungrammatical, and yet adults in study 5a were presented with sentences such as: *The girl*

explained the boy the mistake. It could be that hearing these ungrammatical sentences encouraged adults to interpret the grammatical ones in the same way. The important question is what do our findings tell us about how adults interpreted the ungrammatical sentences in our task?

5.7.2. Explaining the lack of priming with ungrammatical primes in study 5a

Earlier, we suggested that adults might find sentences in which there is conflict between the prime structure and the prime verb's identity unexpected. We also proposed an alternative idea: that the activation of the relevant dative representation might be independent of the verb in that prime. In other words, it might be the syntactic structure of the prime that is important in the activation of representations for structural priming, and not the links between this structure and individual verbs. Our results, however, were not consistent with either of these hypotheses, and instead fit with the third prediction that we made: that ungrammatical sentences do not activate the appropriate dative representation.

These findings conflict with recent results reported by Ivanova et al. (2012) who found that adults who were presented with ungrammatical DOD sentences with non-alternating verbs could be primed to produce DOD responses with alternating verbs. One reason for the disparity between Ivanova et al.'s findings and ours, could, of course be due to differences in study design. For example, the stimuli across the tasks were different: In our study, non-alternating verbs included both DOD- and PD-only verbs, whereas in their study, non-alternating verbs were only ever PD-only. In our

study, all primes were paired with equi-biased target verbs, but in their study, the syntactic preferences of the alternating target verbs, although acknowledged by the authors, were not considered in the interpretation of the results. For example, half of the alternating target verbs in their task (*show*, *chuck*, *loan*, *offer*) are biased towards the DOD (The British National Corpus, 2007); if the bias of the target verb matches the structure of the prime, then participants might appear to show an increased tendency to echo the syntax of the prime when they are simply responding to the bias of the target verb (which happened to be the same as the prime structure). The methodology between the two studies also differed: The adults in our study took turns in repeating primes and producing target descriptions with an experimenter, whilst in Ivanova et al.'s task, adults read (and did not produce) prime sentences on a PC monitor, and described target pictures via a headset microphone which recorded their responses.

Nonetheless, the conflicting results mean that we have arrived at conclusions about the way in which adult representations are linked to the verb lexicon that are different to those made by Ivanova et al. (2012). They suggest that even when the prime verb is ungrammatical in its structure, the structure of the prime is enough to activate the appropriate DOD representation. However, the fact that adults in our study showed structural priming when the prime verb was grammatical in its structure (study 5b), but not when there was conflict between the prime verb and its structure (study 5a) indicates that it is not simply the structure of the prime that is important for the activation of DOD and PD representations: the compatibility between prime verb identity and prime structure matters too. Our findings also allow

us to posit a theory about why the ungrammatical sentences did not activate the relevant dative representations to result in significant structural priming; adults may have found the ungrammatical sentences difficult to understand, forming only representations that were “good enough” for the task (Ferreira, Bailey, & Ferraro, 2002). These representations may have allowed them to produce a dative description of a target image, but may not have included enough detail about whether this structure was a DOD or a PD. Taken together, our findings not only have implications for our understanding about how syntactic representations are stored, but they also provide insight into how the information that we interpret affects how these representations are activated.

5.8. Study 5b: Conclusion

Previous research on adults has indicated that adults are sensitive to prime surprisal such that they are more strongly primed when the bias of the prime verb is unexpected in its structure (Chang, Dell, & Bock, 2006). However, we have found it hard to replicate this effect in adults. In study 3b in chapter 3, we found that adults showed weaker surprisal effects than did children, which we interpreted as suggesting that children have faster learning rates; faster learning rates lead to more substantial weight changes in response to error, and thus more prime surprisal. However, before drawing this conclusion we wanted to explore whether the results could be attributed to adults’ increased familiarity with the prime verb. To explore this idea, we presented adults with sentences that adults might find more unexpected: sentences with verb-structure mismatches containing low frequency verbs

(study 4a), and sentences with verb-structure mismatches containing non-alternating verbs (study 5a). In both studies, we failed to increase the size of the prime surprisal effect in adults. Our original conclusion, then, stands; adults seem to show smaller prime surprisal effects than children.

The findings from the current study also suggest that the structure of the prime alone is not enough for the activation of the relevant syntactic representations that are needed for successful priming: knowledge about verbs also plays a role. In particular, our findings indicate that knowledge about verbs and their argument structure constraints guides the interpretation of sentences and influences how syntactic representations are activated. Thus, our findings again support the idea of a close integration between adult syntactic representations and the verb lexicon.

Chapter 6

The effect of verb semantic class on structural priming in children and adults

6.4.1. Explaining the disparity between the production and comprehension literature

6.4.2. Conclusion

Chapter 6: The effect of verb semantic class on structural priming in children and adults

6.1. Study 6: Introduction

The previous chapters focused on investigating prime surprisal with dative sentences. In this chapter, we move away from this structure to explore how children's knowledge of the passive develops.

An important question not addressed by the child priming studies is how children's knowledge of syntactic structure interacts with their knowledge about the behaviour of particular verbs. This means that in comparison to the adult literature, we know little about the relationship between children's abstract syntactic representations and the developing verb lexicon. In chapter 3, we assessed the effect of verb-syntactic preferences on priming in both children and adults. The study found evidence of abstract structural priming at all ages and, although the lexical boost was apparent only in adults, the identity of the target verb (target verb bias) and the prime verb (prime surprisal) influenced both children's and adults' structure choice. This was interpreted as evidence that children acquire abstract knowledge of structure and also develop knowledge about verb-argument structure preferences early in acquisition.

These findings, however, are only representative of children's and adults' knowledge of the dative construction. In order to develop an account of verb-syntactic development, it is important to establish whether these effects can be generalised, or whether they are simply isolated to certain structures. The focus of the current study, therefore, was to move to a

different structure – the transitive – and investigate whether children's and adults' knowledge about the verb-structure preferences of verbs from different semantic classes influences their structure choice for transitive sentences.

Like the dative, the transitive allows the alternation of some verbs between two semantically-similar but syntactically different structures. In the active structure, the agent role is assigned to the verb's subject, and the patient role to the verb's object (1a). These semantic roles are reversed in the passive so that the agent role is assigned to the verb's object, and the patient role to the verb's subject (1b).

Example 1

(a)	*The cat*	*caught*		*the mouse*
	[AGENT]	[VERB]		[PATIENT]
(b)	*The mouse*	*was caught*	*by*	*the cat*
	[PATIENT]	[VERB]		[AGENT]

Research has suggested that children have some sort of abstract representation of the active structure in English from reasonably early on in acquisition (Naigles, 1990). In comparison, they seem not to be productive with the English passive structure until later - around the age of three (Huttenlocher, Vasilyeva, & Shimpi, 2004; Tomasello, Brooks, & Stern, 1998, though see Abbot-Smith and Behrens, 2006, for evidence of productive use of the German *sein*-passive from the age of 2;4). Moreover, this knowledge appears to be limited such that until around the age of six, they find passive

sentences with ‘non-actional’ verbs harder to understand than passive sentences with ‘actional’ verbs (e.g., Borer & Wexler, 1987; Fox & Grodzinksy, 1998; Hirsch & Wexler, 2004; Maratsos, Fox, Becker, & Chalkley, 1985). Consider the following example:

Example 2

(a) Actional:	*The mouse was **caught** by the cat*
(b) Non-actional Experiencer-theme:	*The mouse was **loved** by the cat*
(c) Non-actional Theme-experiencer:	*The mouse was **frightened** by the cat*

Young children find it easier to interpret sentences with agent-patient (AP) verbs like 2(a) where the verb (*catch)* is highly transitive or physical, and there is a clear change in state to the patient. In comparison, they find it harder to understand sentences with experiencer-theme (ET) verbs like 2(b) where the verb is less transitive and more psychological. Similarly, children have been shown to make more errors with passive sentences that contain ET verbs (e.g., *ignore*) than with prototypically transitive AP verbs (e.g., *pat*) or theme-experiencer (TE) verbs (see example 2c) (e.g., *frighten*) (Messenger, Branigan, McLean, & Sorace, 2012). One possible explanation of this asymmetry in children’s comprehension is that there are semantic constraints on the passive structure such that initially, they are only able to abstract across highly transitive actional verbs, perhaps because it is easier to conceptualise the mapping of semantic to syntactic roles with these types of verb, or because these verbs have passive participles that readily allow an adjectival interpretation (Borer & Wexler, 1987). However, with development,

they learn to generalise the structure to less transitive psychological verbs (Maratsos et al., 1985). Thus, the findings suggest that children's early knowledge of the passive is such that they do not represent verbs from different semantic classes in the same way.

The possibility of such a constraint, however, has been called into question. This is because recent evidence from structural priming has revealed that children as young as three years are able to generalise across passive sentences with transitive verbs from different verb classes. Messenger et al. (2012) presented 3-4 year olds and adults with prime sentences containing TE and ET verbs and found that children were equally as likely to be primed after passive sentences with ET verbs as they were after passive sentences with TE verbs. This suggests that they have, by this age, formed a common structural representation for the passive. Thus, the literature is conflicting: children can be primed to produce passives after passive sentences with both ET and TE verbs, and yet they have difficulty understanding passive sentences with ET compared to TE verbs.

To complicate the picture further, Ambridge, Bidgood, Pine, Rowland, and Freudenthal (in submission) showed that while TE verbs were rated by 9-10 year olds as equally grammatical in both the passive and the active structure, ET verbs were rated as less acceptable if they were presented in the passive. Ambridge et al. claim that this is because ET verbs possess fewer properties that relate to the semantics of the passive compared to TE verbs. Specifically, ET verbs have poor compatibility with the semantics of "affectedness", where A affects B (with B being the subject) - a feature

proposed by Pinker (1989) as being positively related to a verb's passivisability. Consider the following sentences:

Example 3

(a) TE-verb: *Bob was shocked by Wendy*

(b) ET-verb: *Marge was remembered by Homer*

The verb in sentence 3(a) is compatible with the meaning associated with the passive because the subject is highly affected (i.e., A (*Wendy*) has clearly affected B (*Bob*) such that there is clear change of state to B). In contrast, the subject in 3(b) is less affected and so the verb in this sentence is less compatible with the passive's meaning (i.e., A (*Homer*) has not clearly affected B (*Marge*); the fact that Marge was remembered has not changed her state). The findings from Ambridge et al. suggest that: a) the greater the extent to which a verb instantiates the semantic property of 'A affects B', the more likely that verb is to be rated as grammatical in the passive structure, and b) since TE verbs denote greater affectedness than ET verbs, passive sentences with TE verbs are likely to be rated as more acceptable. Thus, there is some evidence that, at least by 9 years of age, children have knowledge about the way in which verbs from different semantic classes behave, and that this knowledge affects what they perceive to be grammatical.

In sum, two- to three-year old children have trouble understanding passive sentences with ET verbs compared to TE verbs. They also, at 9 years, rate passive sentences with ET verbs as less acceptable than passive

sentences with TE verbs. Three- to four-year olds are, however, primed just as much by passive sentences with ET verbs as they are by passive sentences with TE verbs. These results demonstrate a clear contradiction. The aim of the current study, therefore, was to use a slightly different paradigm to explore whether children's knowledge about the verb-structure preferences of ET and TE verbs influences their structure choice for transitive sentences. Messenger et al. found evidence of abstract priming in children as young as three with verbs from these classes, which suggests that that the presentation of a passive sentence activates a passive representation irrespective of the verb in that sentence. It is possible, however, that the three-year olds in their task attended only to the prime structure because they were not familiar with the meaning of the ET and TE verbs. As we were interested in investigating what knowledge children have about verbs and their argument structure constraints, it was important that the children in our study grasp the meaning of the sentences. To increase the chances of this, the youngest children that we tested were aged between five and six years old - slightly older than in Messenger et al.'s study. Furthermore, because we wanted to learn whether this knowledge is the same or differs for children and adults, we tested young children (aged 5-6 years), older children (aged 9-10 years), and adults on the same task.

As already discussed, both error-based models of processing (such as the Dual-Path model) and experimental findings (our results in chapter 3) have revealed that unexpected sentences can yield larger priming effects, especially in children. In particular, sentences in which the bias of the prime verb mismatches the structure in which it appears, lead to surprisal effects

(Bernolet & Hartsuiker, 2010; Chang, Dell, & Bock, 2006). On this view, if children and adults view ET verbs as less compatible with the passive structure than TE verbs, then presenting ET verbs in a passive (e.g., a mismatch; *Wendy was remembered by Bob*) should result in stronger priming (prime surprisal) than presenting TE verbs in a passive (e.g., a match; *Wendy was shocked by Bob*). Evidence of prime surprisal with ET verbs might indicate weak links between these verbs and syntactic representations of the passive, which could help to explain why children seem to have difficulty understanding passive sentences with this class of verb.

6.1.1. The current study

The current study used structural priming and prime surprisal to assess whether children and adults have acquired knowledge about the semantic properties related to ET and TE verbs such that it influences their structure choice in a priming task. In doing so, the study aimed to better understand how children's and adults' representations for the passive structure are linked to their knowledge about verb-specific preferences, as well as whether there are age-related differences in this knowledge.. Thus, the following work extends the previous study (study 3b) by exploring whether the relationship between syntactic structure and the verb lexicon differs across structures.

The first aim was to replicate the findings of Messenger et al., (2012) by examining whether 5-6 year olds, 9-10 year olds and adults show evidence of abstract structural priming with both experiencer-theme (e.g., *like*) and theme-experiencer (e.g., *irritate*) verbs. If, as Messenger et al.

suggest, children have an abstract representation of the passive that is not initially limited to highly transitive verbs, then all age groups should show evidence of abstract structural priming with prime sentences containing ET and TE verbs. In addition, we examined whether there were any differences in the size of the priming effect according to age, since such differences might indicate developmental changes in the strength of syntactic representations.

The second aim was to investigate whether children are sensitive to the verb-structure preferences of verbs from different semantic classes such that this influences the strength of the priming effect. If ET verbs are less compatible with the semantics of the passive (i.e., affectedness), children might, be more surprised and thus, more strongly primed by passive sentences with ET verbs than by passive sentences with TE verbs (which are more compatible with the semantics of the passive). As in study 3b, we also investigated whether the magnitude of the prime surprisal effect varied with age. If we were to find differences across age, this might reflect developmental changes in the strength of verb-structure links, and could potentially explain why young children find it difficult to interpret passives with ET verbs even though they can be primed by them.

6.2. Study 6: Method

6.2.1. Participants

A total of 177 participants was tested. One hundred and nineteen monolingual English-speaking children were recruited from schools in the Liverpool area. Sixty of these children (33 female) were between five and six

years old (mean age 5;6, age range 5;2-6;3) and 59 children (25 female) were between nine and ten years old (mean age 9;4, age range 9;1-10;4). A further 58 monolingual English-speaking adults (44 female) were recruited from the University of Liverpool student participation pool. Participants were tested individually in either their classroom or in the language development laboratory at the University of Liverpool.

6.2.2. Design and Materials

6.2.2.1. Design

The study used a 3 x 2 x 2 mixed design. Age (5-6 year olds/9-10 year old/Adults) was the between-subjects variable. The two within-subjects variables were Prime Type (active and passive) and Verb Type (ET and TE verbs). The dependent variable for the descriptive analyses was the proportion of transitive responses that were passive (i.e., a ratio of passive responses over the sum of passive and active target responses). For the inferential analyses, the dependent variable was binary (1 = passive, 0 = active)

6.2.2.3. Visual stimuli

Eighty video cartoon animations were created in Anime Studio Pro and were presented in E-Prime 2.0. The cartoons included three pairs of donor and recipient characters that are familiar to young British children and have proper noun names: *Bob (the Builder) and Wendy, Marge and Homer (Simpson),* and *Lisa and Bart (Simpson)*. A further three pairs of donor and recipient characters were referred to with determiner+noun NPs: *the prince*

and the princess, the king and the queen, the boy and the girl. Donor and recipient characters were always paired together (e.g., *Wendy* was always paired with *Bob*, and *the prince* was always paired with *the princess*). Forty-eight of the animations depicted actions that can be described with transitive sentences (16 depicted experiencer-theme events; 16 depicted theme-experiencer events; and 16 depicted agent-patient events). Thirty-two others were used as fillers and depicted non-causal actions that can be described with intransitive sentences. Eight of the animations that were used as fillers were also used in a practice session. Each prime picture was always paired with a target picture that included different characters from those in the prime.

Four bingo boards were created on which to place counters during the 'game'. Two of these boards included a grid of four squares and were used in a practice session before the actual experiment. The other two boards were used in the experiment and contained nine squares.

6.2.2.4. Sentence stimuli

Sixteen different reversible and passivizable prime verbs were selected for this task. Eight of these were experiencer-theme (ET) verbs, chosen because they were rated by children in Ambridge et al. (in submission) as more ungrammatical in the passive than in the active structure: *like, believe, hear, remember, listen to, understand, love,* and *watch*. The other eight were theme-experiencer (TE) verbs rated by the same children as equally acceptable in both structures: *distract, surprise, irritate, shock, annoy, tease, startle,* and *disturb.* All prime verbs were paired with eight agent-patient (AP)

target verbs that were also rated as acceptable in both the passive and the active: *avoid, hug, pat, squash, chase, lead, hold,* and *call*.

Eighty different sentences were created to describe the 80 video cartoon animations. Thirty-two of these sentences described 16 different cartoon animations (two animations for each verb). These sentences were used as primes and depicted ET events. Sixteen of these sentences described each of the cartoons using a passive structure (e.g., *Marge was believed by Homer*), and another 16 sentences described the same cartoons using an active structure (e.g., *Homer believed Marge*). A further 32 prime sentences described 16 different cartoon animations that depicted TE events (two animations for each verb). Sixteen of these sentences described each of the cartoons using a passive structure (e.g., *Homer was annoyed by Marge*), and another 16 sentences described the same cartoons using an active structure (e.g., *Marge annoyed Homer*). Thirty-two sentences were used as fillers and used an intransitive structure (e.g., *The princess jumped)*. Unlike study 3b, target verb stems were not created because of the nature of the task.

Each verb was presented twice per participant: once in a passive, and once in an active. Each participant was exposed to 16 prime-target pairs, which alternated with filler-filler pairs used to minimize priming effects between pairs. Overall, each participant was presented with, and produced, 64 sentences in total. No participant was asked to produce the same prime sentence twice and all participants were exposed to an equal number of prime-target pairs from each of the prime conditions.

Since the task only investigated lexically-independent priming, all participants were exposed to sentences in which verbs in prime and target sentences were different. As in study 3b, pairs of characters appeared equally often in prime and target sentences and, to avoid lexical overlap (other than that of the verb), characters in primes were always different from the characters in the targets with which they were paired. Furthermore, primes that contained determiner noun phrases (e.g., *the princess*) were always followed by targets with proper noun phrases (e.g., *Wendy*), and vice versa, to limit the possibility that participants would be primed by the prosody of the prime sentence. Sentences were always presented in the past tense – although it was noted that presenting sentences in the present progressive form might avoid participants interpreting passives as adjectival (see Messenger et al., 2012). As in all of the experimental studies carried out so far, counterbalance groups were created to control for sentence-specific preferences (all have been discussed previously).

6.2.3. Procedure

The study used a confederate-scripted dialogue method. Similar to that used in study 3b, the experiment was conducted in the form of a bingo game in which the experimenter and the participant took turns in describing cartoon videos on a laptop computer. In this task, however, the computer and not another experimenter, acted as a confederate. A pre-recorded voice embedded into the animations announced the prime, target, and filler verbs. The computer was also programmed to provide pre-specified answers as to whether or not players could receive a counter after their response.

The experimenter introduced all of the characters involved in the task to the participant by showing them a sheet of paper on which all of these characters appeared. They then both sat in front of the computer side by side – the experimenter on the left and the participant on the right. The experimenter pressed the spacebar key on the laptop which initiated an animation that appeared on the left-hand side of the screen. Exactly three-seconds after the onset of the animation, a pre-recorded voice embedded in the animation announced the prime verb (either an ET or TE verb)[1]. Once the animation had finished, the experimenter, using either an active or a passive structure, described what had happened in the animation, making sure to use that verb (e.g., *The girl distracted the boy/The boy was distracted by the girl*). This description served as the prime sentence and was immediately repeated by the child. Following this, a different animation was played on right-hand side of the screen. Again, three-seconds after onset, a pre-recorded voice announced the target verb (which was always an AP verb). The child then described the animation using that verb. This technique was used to ensure that the target sentence contained the target verb. After each sentence, either a happy or a sad face appeared on the screen. A happy face meant that the experimenter or participant was rewarded with a counter to place on their bingo board. A sad face meant that no counters were rewarded[2]. Each prime-target pair was immediately followed by an intransitive filler-filler pair. The first person to fill the bingo grid with counters

[1] We decided that production of the verb should occur three seconds after the animation's onset because this coincided with the initiation of the action in the event (e.g., for an animation that depicts Bart distracting Lisa, Bart begins to distract Lisa exactly three seconds in to the animation). All of the verbs were produced by the same female voice, and, as much as possible, used the same intonation.
[2] It was made clear to all participants that faces were presented randomly, and that a happy or a sad face did not at all signify a correct or an incorrect response, respectively.

was the winner of the game and the experiment was designed so that the participant always won. Before running the experiment using the nine-squared bingo board, a practice session using the four-squared board was carried out to ensure that the children understood the task.

6.2.4. Coding

Target responses were recorded online by the experimenter using the keyboard response coding function of E-Prime 2.0 (the experimenter pressed ‘p’, ‘a’, or ‘o’ depending on whether the participant produced a passive, active, or ‘other’ response, respectively, and these responses were automatically recorded and collated into a data file by E-Prime). The experiment was also audio-taped, allowing the transcription and coding of the utterances off-line. Some of the children needed prompting by the experimenter to produce the prime and the entire target sentence correctly. However, because these occasions were minimal, only a strict level of coding was employed. To qualify for strict coding, the prime and target sentence had to be produced correctly with no more than one prompt. A target response was considered a passive if it contained the correct target verb followed by a ‘by’ phrase, as well as the two semantic roles in the correct order (i.e., patient>verb>agent). A response was considered an active if it contained the correct target verb with the two semantic roles in the correct order (agent>verb>patient). Responses coded as ‘other’ were those where: a) the participant failed to repeat the prime correctly (even after help), b) the participant produced the incorrect target verb and, c) the participant reversed the semantic roles (e.g., producing *Marge was annoyed by Homer*,

when the animation depicts Marge as the agent of the verb, and Homer as the patient). Analysis shows that the 5-6 year olds, 9-10 year olds, and adults produced 9%, 2.3%, and 1.9% of 'other' responses, respectively.

6.3. Study 6: Results

The aims were: 1) (i) to replicate the findings of Messenger et al., (2012) by examining whether children and adults show evidence of abstract structural priming with both experiencer-theme (e.g., *like*) and theme-experiencer (e.g., *irritate*) verbs, and (ii) to examine whether the structural priming effect varied with age, and 2) (i) to investigate whether children and adults are more strongly primed by passive sentences with ET verbs than passive sentences with TE verbs (i.e., prime surprisal), and (ii) to examine whether the prime surprisal effect varied with age.

A variety of logistic mixed effect models were fitted to examine the data and, as before, all of the models were calculated using the *glmer* function of the *lme4* package in R (lme4: version 1.1-6; R Core Team, 2012). In all cases, the dependent measure was the structure produced by the participant (passive = 1, active = 0). Maximal models were fitted and the random slope structure was simplified until the model converged following the procedure in Barr, Levy, Scheepers, and Tily (2013). Model comparison was used to compute chi-square and p-values.

6.3.1. Structural priming in children and adults

The first aim was to test whether the findings of Messenger et al. (2012) could be replicated by examining structural priming in children and adults.

The mean proportion of passive responses after passive and active primes was calculated (see Table 6.1). Structural priming was demonstrated if a greater proportion of passive responses were produced after passive primes than after active primes.

Table 6.1 *Mean (SD) proportion of passives produced after active and passive primes, and size of priming effect calculated both as the proportion of passives produced in each prime condition (difference score) and as effect sizes (Cohen's d)*

Age	**Prime Type**		**Size of priming effect**		
	Active	**Passive**	**Difference Score**	**Standard Error**	**Cohen's *d***
5-6	0.05 (0.22)	0.12 (0.32)	0.07	0.02	0.40
9-10	0.02 (0.13)	0.05 (0.21)	0.03	0.01	0.24
Adults	0.06 (0.25)	0.20 (0.40)	0.14	0.02	0.59

Initial descriptive statistics revealed that all age groups produced more passive responses after passive primes than they did after active primes. The first model included as fixed effects: a) Age (5-6 year olds/9-10 year olds/Adults), and b) Prime Type (passive/active). The model included by-subject random slopes for Prime Type. The results revealed a main effect of Prime Type ($\beta = 1.74$, $\chi^2(1) = 21.8$, $p < .001$), indicating that the participants produced more passive responses after passive primes than after active primes with both ET and TE verbs. There was also a main effect of Age ($\beta = 0.09$, $\chi^2(1) = 11.7$, $p < .001$), which shows that adults produced more passives than children. However, there was no interaction between Prime

type and Age (β = 0.02, $\chi^2(1) = 0.36$, $p < .06$) which suggests that the magnitude of the priming effect was the same across all age groups (see Figure 6.1). Nevertheless, consultation of Figure 6.1 revealed overlapping error bars for the 9-10 year olds. Thus, although 9-10 year olds produced more passive target responses after passive primes than after active primes, this difference appeared not to be significant. To confirm this, three separate models were run on each age group, and all models included by-subject random slopes for Prime Type. For the 5-6 year olds, there was a main effect of Prime Type (β = 2.14, $\chi^2(1) = 6.46$, $p < .05$). Likewise, the adults also showed a main effect of Prime Type (β = 1.83, $\chi^2(1) = 18.88$, $p < .001$). As expected, however, there was no main effect of Prime Type for the 9-10 year olds (β = 1.75, $\chi^2(1) = 2.49$, $p = .11$).

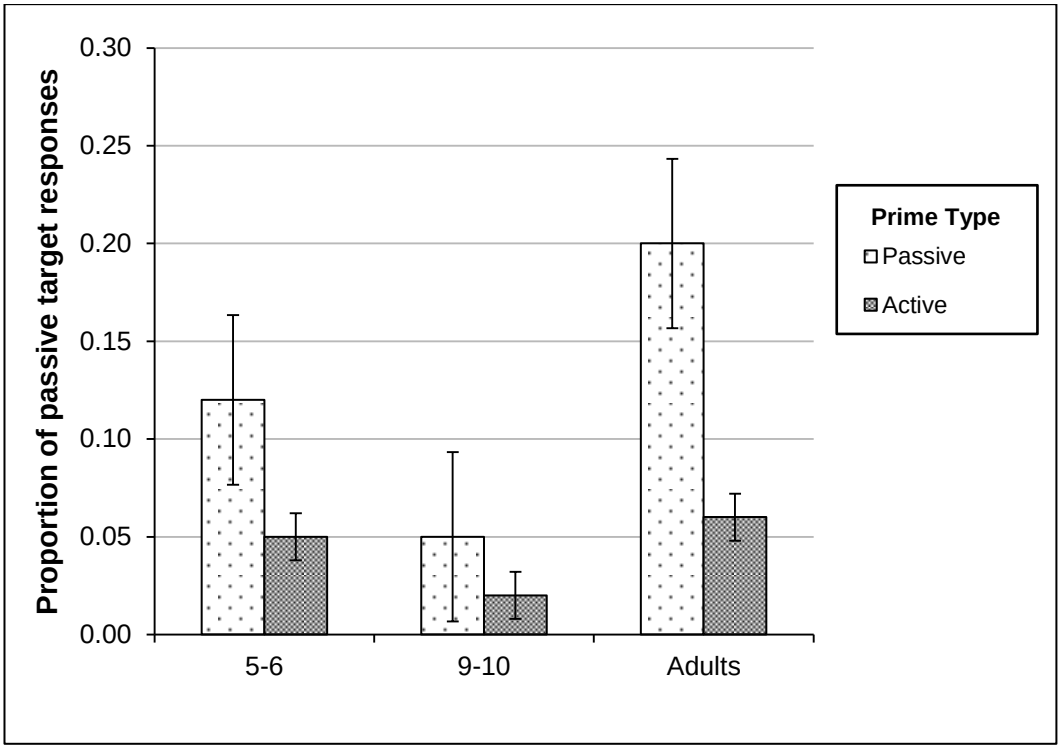

Figure 6.1 *Mean proportion of passive responses after passive and active primes (error bars indicate standard error)*

6.3.2. The effect of verb semantic class on structural priming in children and adults

The second aim of the study was to explore whether children and adults are sensitive to verb semantic preferences such that this influences their structure choice. To do this it was observed whether the strength of the priming effect varied as a function of the prime verb's semantic class. Specifically, the study tested whether children and adults were more strongly primed by passive sentences with ET verbs than passive sentences with TE verbs (i.e., prime surprisal).

Table 6.2 *Size of priming effect for ET and TE verbs, calculated both as the proportion of passives produced in each prime condition (difference score) and as effect sizes (Cohen's d)*

Age	**Experiencer-theme verb**			**Theme-experiencer verb**		
	Difference Score	**Standard Error**	**Cohen's *d***	**Difference Score**	**Standard Error**	**Cohen's *d***
5-6	0.05	0.02	0.25	0.09	0.02	0.36
9-10	0.02	0.02	0.23	0.04	0.02	0.38
Adults	0.14	0.02	0.70	0.13	0.04	0.54

The second model included as fixed effects: a) Age (5-6 year olds/9-10 year olds/Adults), b) Prime Type (passive/active), and c) Verb Type (experiencer-theme/theme-experiencer). The model also included by-subject random slopes for Prime Type and Verb Type. The results revealed a main effect of Prime Type ($\beta = 1.42$, $\chi^2(1) = 74.3$, $p < .001$), indicating that the participants produced more passive responses after passive primes than after active primes. There was also a main effect of Age ($\beta = 0.09$, $\chi^2(1) = 10.8$, $p < .05$),

which shows that adults produced more passives than children. Importantly, there was no interaction between Prime Type and Verb Type which indicates that the strength of the priming effect was not dependent on the type of verb in the prime sentence. In other words, participants were primed just as much by passive sentences with ET verbs as they were by passive sentences with TE verbs.

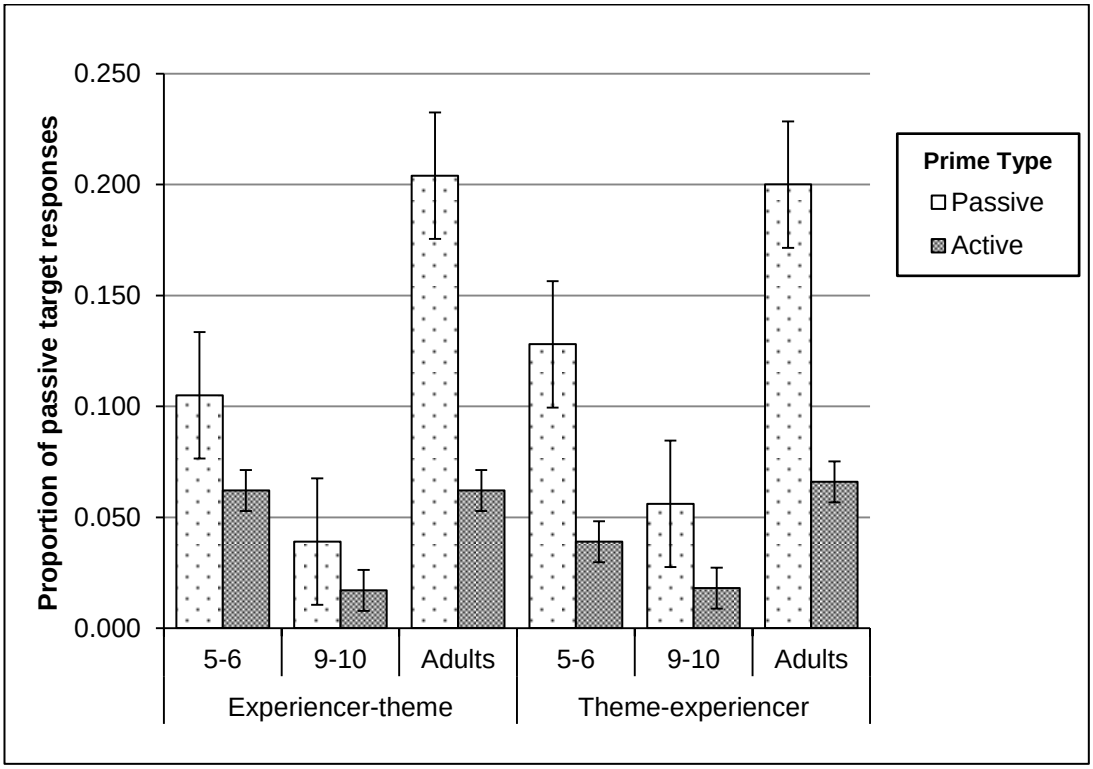

Figure 6.2 *Mean proportion of passive responses after passive and active primes for ET and TE verbs (error bars indicate standard error)*

6.3.2.1. Analyses by age

It was noted that the 9-10 year olds produced only 30 passive target responses overall (compared to the 5-6 year olds who produced 73, and adults who produced 121). Thus, it was considered possible that such a small number of passive responses from this age group may have masked

any interactions between the priming effect and the type of prime verb. For this reason, three separate models were fitted to each age group. For the 5-6 year olds, there was a main effect of Prime Type (β = 2.30, $\chi^2(1) = 6.46$, $p < .05$) and a marginal interaction between Prime Type and Verb Type (β = -1.41, $\chi^2(1) = 4.17$, $p < .05$), indicating that for this age group, and contrary to the prediction, priming was stronger for TE verbs than for ET verbs. This was confirmed by a comparison of effect sizes (Cohen's *d* = 0.25 for ET verbs vs. 0.37 for TE verbs). For the 9-10 year olds, there was a main effect of Prime type (β = 1.92, $\chi^2(1) = 10.8$, $p < .05$) but no effect of Verb Type and no interaction. Similarly, for the adults there was a main effect of Prime type (β = 1.84, $\chi^2(1) = 19$, $p < .001$), but no effect of Verb Type and no interaction. So, it appears that for the youngest children, the type of verb that was presented in the passive did marginally influence their structure choice. Contrary to the prediction, however, priming was stronger for TE verbs than for ET verbs. In other words, priming was stronger, not weaker, for the TE verbs, which are more compatible with the semantics of the passive, than for the ET verbs.

6.3.3. Addition of mean age of acquisition as a variable

Given that the semantic class of the prime verb influenced priming for the youngest children only, but in the opposite direction to that predicted, we considered whether there may be some other feature of the verb that might explain the pattern of results observed. It was noted that the current study used transitive verbs acquired over a fairly wide age range (see Appendix for a table detailing the mean ages at which the verbs used in the task are

acquired). For example, the ET verb *like* is learned quite early in development at around the age of 3.69 years. In comparison, the TE verb *disturb* is not learned until much later at around 8.22 years (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012). In fact, six out of the eight TE verbs (75%) that were used in the study are verbs that are, on average, only learned after the age of seven. This could explain why the youngest children in the study were more strongly primed by passive sentences with TE verbs; these verbs are surprising to these children when presented in the passive because they are still in the process of learning their argument structure properties. To investigate this, a further three models were fitted to each age group. This time, the models included: a) Prime Type (passive/active) and b) Mean Age of Acquisition of the prime verb (AoA)[3] as fixed effects. By-subjects random slopes for Prime Type, AoA, and Prime Type crossed with AoA were included. For the 5-6 year olds, there was a main effect of Prime Type ($\beta = 2.32$, $\chi^2(1) = 5.16$, $p < .05$). There was also a main effect of AoA ($\beta = -0.50$, $\chi^2(1) = 5.53$, $p < .05$), indicating that fewer passives responses were produced with prime verbs that are acquired later on. Interestingly, there was an interaction between Prime Type and AoA ($\beta = 0.46$, $\chi^2(1) = 10.8$, $p < .05$) indicating that priming was also stronger for late acquired verbs, as predicted. In other words, priming was stronger for verbs that were less well known. For the 9-10 year olds there was a main effect of Prime type ($\beta = 1.45$, $\chi^2(1) = 1.45$, $p < .05$), but, no effect of AoA and no interaction. Likewise, adults showed a main effect of Prime type ($\beta = 1.60$, $\chi^2(1) = 18.8$, $p < .001$) but no effect of AoA and no interaction.

[3] The mean age of acquisition for each verb was taken from Kuperman, Stadthagen-Gonzalez, and Brysbaert (2012); a table of these verbs can be found in the Appendix.

6.3.4. Summary of results

The current study found that 5-6 year olds and adults showed evidence of abstract structural priming with sentences containing ET and TE verbs. Although the 9-10 year olds produced more passive responses after passive primes than after active primes, this effect did not reach significance. Adults also produced more passives than younger and older children, regardless of the prime structure, with the 9-10 year olds producing even fewer passives than the youngest children. Analysis of the entire dataset revealed that the size of the priming effect did not vary with the type of verb in the prime. However, when analysed by age group, the 5-6 year olds were, in fact, marginally more strongly primed by TE verbs than ET verbs. When the mean age of acquisition of the prime verb was also considered, how well prime verbs were acquired did not affect the strength of the priming effect for 9-10 year olds and adults. However, for the 5-6 year olds priming was stronger for verbs that were less well known.

6.4. Study 6: Discussion

The research on children's knowledge of the passive is somewhat conflicting: On the one hand, the comprehension literature has suggested that young children's abstract knowledge of this structure is constrained to prototypically transitive verbs such as agent-patient (AP) verbs (Maratsos et al., 1985), and that older children (aged 9-10) rate passive sentences with theme-experiencer (TE) verbs (which instantiate the semantic properties associated with the passive) as more acceptable than passive sentences with

experiencer-theme (ET) verbs (which tend not to, Ambridge et al., in submission). On the other hand, the production priming literature has revealed that children as young as three are primed by sentences with ET and TE verbs (Messenger et al., 2012). The focus of the current study, therefore, was to better understand how children's representations of the passive structure are linked to their knowledge about verbs and their argument structure preferences, and to discover whether this knowledge changes with age. To do this, we used a structural priming paradigm to test 5-6 year olds, 9-10 year olds and adults with prime sentences containing ET and TE verbs. The first aim was to replicate the findings of Messenger et al., which showed that young children and adults are primed by sentences containing ET and TE verbs, and then to examine whether structural priming varied with age. The second aim was to investigate whether children and adults are more strongly primed by passive sentences with ET verbs than passive sentences with TE verbs (i.e., prime surprisal), and to examine whether the prime surprisal effect varied with age.

The findings of Messenger et al., were replicated; all age groups were significantly more likely to produce passive target sentences (e.g., *The girl was chased by the boy*) after hearing and repeating passive primes (e.g., *Bob was liked by Wendy/Bob was shocked by Wendy*) than active primes (e.g., *Wendy liked Bob/Wendy shocked Bob*) with both ET (e.g., *like*) and TE (e.g., *shock*) prime verbs. This finding is important for two reasons: First, it indicates that by the age of five, children have built an abstract representation for the passive that enables them to generalise across other similarly-structured sentences. As such, this finding is a strong indicator that

children's abstract knowledge is not isolated to one syntactic structure (such as the dative). Second, it suggests that children possess abstract representations of the passive that are not limited to one particular verb semantic class. This seemingly goes against the claim that children's early knowledge of the passive is constrained to highly transitive, namely AP verbs (Maratsos et al., 1985; Sudhalter & Braine, 1985).

We also examined whether the magnitude of the priming effect was different for children and adults, since differences across age might indicate developmental differences in the activation and strength of passive representations. Although, the effect did not reach significance, we found that adults were more strongly primed than the 5-6 and 9-10 year olds. They also produced significantly more passive responses than 5-6 and 9-10 year olds regardless of the prime structure. In other words, the presentation of a passive sentence was more likely to activate a passive representation for adults than for children, and passives, in general, were produced more frequently by adults than by children. This pattern could be related to (or possibly a consequence of) the passive structure's infrequency in the input. Given that passives are rare in adults' speech to children (Gordon & Chafetz, 1990), children will have less experience and, thus, fewer exemplars from which to determine abstract patterns and formulate robust representations of the passive structure. Support for this idea comes from work by Kline and Demuth (2010) who attribute the acquisition of the passive to the frequency with which this structure is heard in the input. In their analysis of the Sesotho Corpus (comprising 98 hours of conversations between children and their peers, siblings, and adults), they reported that Sesotho-speaking children

who heard a high frequency of passives in the input, also spontaneously produced full passives early in acquisition (2;8). This is much earlier than English-speaking children who hear far fewer passives and tend only to produce truncated (e.g., *The dolly got kicked*) and adjectival passives (e.g., *It was broken*) at this age (Israel, Johnson, & Brooks, 2000). In the same way, a number of researchers have revealed that languages in which the passive is produced relatively late in children's spontaneous speech, are often those in which the passive is less frequent in the input (e.g., the passive appears at 5 years old in German, de Villiers, 1984, and at 8 years old in Hebrew, Berman, 1985). Given that children are sensitive to distributional information in the input (e.g., Gomez & Gerken, 2000; Saffran & Wilson, 2003), this could explain the age-related differences in structural priming and passive production in our study: Adults will have had more experience with the passive than children and, thus will have had more opportunity to strengthen their syntactic representations for this structure.

An unexpected finding, however, was the absence of structural priming for the 9-10 year olds. Although they did produce more passive responses after passive primes than after active primes, this effect was non-significant. The youngest children showed evidence of priming, which suggests that the presentation of passive sentences activates a passive representation for this age group. It seems unreasonable, therefore, to interpret the lack of priming for the older children as a developmental difference in the strength of their representations. We can more likely attribute this finding to the fact that, for some reason, the 9-10 year olds produced hardly any passive responses regardless of the prime structure. It

is not immediately clear why they behaved in this way, but one possibility is that they were more focused on the game element of the task, which may have distracted them from attending to the prime structure.

The second aim of the study was to assess whether children and adults store knowledge about the verb-structure preferences of verbs from different semantic classes such that it influences the language that they produce. The motivation for this was to provide insight into how children represent the links between these verbs and representations for the passive structure. If children represent knowledge about experiencer-theme (ET) and theme-experiencer (TE) verbs differently, then the magnitude of the priming effect might vary across prime verb semantic class. In particular, if children have weak links between ET verbs and syntactic representations of the passive (because these verbs are less compatible with the semantics of the passive), then they might be more strongly primed by passive sentences with ET verbs than passive sentences with TE verbs (prime surprisal; Chang, Dell, & Bock, 2006). Analysis of the entire dataset revealed that for all age groups, the size of the priming effect did not vary with the type of verb in the prime sentence. In other words, passive prime sentences with ET verbs did not yield stronger priming effects than passive prime sentences with TE verbs for both children and adults. However, when the data were analysed separately, it was found that the 5-6 year olds were, in fact, marginally more strongly primed by TE verbs than ET verbs. This finding was surprising, and at first glance, hard to explain. This is because not only do TE verbs denote a greater degree of prototypical transitivity than ET verbs (and so should be easier to interpret in passive sentences), but they also instantiate the

semantics of the passive (i.e., affectedness) to a greater extent than that of ET verbs (Ambridge et al., 2012). As such, children might be expected to have stronger links between TE verbs and syntactic representations of the passive, and thus, show less evidence of surprisal with passive sentences containing these verbs. However, whilst the categorical division of ET and TE prime verbs into two semantic classes allows the testing of this prediction, it does not account for the fact that the prime verbs from both of these semantic classes are acquired (on average) across a fairly wide age range. In fact, some of the prime verbs used in the study tend to be acquired at ages not yet reached by the youngest participants. For example, the ET verb *watch,* has an average age of acquisition of 4.33 years, while the mean age at which *startle*, a TE verb, is learned is 9.17 years. So, even though these verbs vary in terms of their compatibility with the semantics of affectedness (a property positively associated with a verb's passivisability), they also vary substantially with regards to how well they are known by children. For this reason, we re-analysed the data so that it examined the effect of priming as a function of the mean age of acquisition of the prime verb (AoA), and not as a function of the prime verb's semantic class. This analysis revealed an interesting finding: For the 9-10 year olds and the adults, AoA did not affect the magnitude of the priming effect. For the 5-6 year olds, however, priming was weakest for prime verbs acquired early in development and strongest for the verbs acquired later on. So, while priming seems not to be modulated by the semantic class to which a prime verb belongs, it is affected by how well a prime verb is known.

This prime surprisal effect (that the youngest children were primed most strongly by the prime verbs that they knew the least) supports the idea that verb-structure links are developed via an error-based learning mechanism. This type of mechanism is instantiated in the Dual-path model (Chang, Dell, & Bock, 2006). The model makes predictions about upcoming words in a sentence, and uses the error between the predicted and actual output to adjust the connections weights between representations. In this way, weights are only changed and thus, learning only occurs when a prediction is not met. Material that is less well known will result in greater prediction error and larger weight changes, and as such is subject to greater learning. So, even though the ET verb *watch* has a poor fit with the passive structure, 5-6 year olds are less likely to be surprised by a passive sentence containing this verb because it is acquired early in development. In other words, they will have more experience with *watch,* and so are likely to have established links between this verb and their representation of the passive. In comparison, despite the TE verb *startle* demonstrating the semantic properties that are positively associated with the passive, 5-6 year olds are likely to find a passive sentence with this verb unexpected because it is not learned until later on. As such, they are likely to have much less experience with *startle*, in which case they may not yet have developed (or still be in the process of creating) links between this verb and their representation of the passive. In the same way, this type of learning can also account for why AoA did not affect the strength of the priming effect for the 9-10 year olds and the adults; the 'oldest' prime verb, *irritate*, is acquired at the mean age of 9.47 years. As both of these age groups are likely to have experience with most, if

not all, of the verbs, then it is unlikely that priming will be affected by the age at which these verbs are acquired. The separation of verbs into semantic class is perhaps too coarse a division for investigating the type of knowledge that children store about passive verb-structure preferences. Nevertheless, the finding that 5-6 year olds were more strongly primed by the verbs they knew the least can at least explain why they were more marginally strongly primed by passive sentences with TE verbs; 75% of the TE verbs are not acquired until up to four years after the age of some of the youngest participants.

6.4.1. Explaining the disparity between the production and comprehension literature

Although our findings have shed some light onto how children's representations of the passive are linked to their knowledge about verbs, they are still unable to explain the comprehension literature: why is that 3-6 year old children seem to have trouble interpreting passives with ET verbs (Fox & Grodzinksy, 1998; Hirsch & Wexler, 2004; Maratsos, Fox, Becker, & Chalkley, 1985)? The results from the current study along with those of Messenger et al. (2012) show that it is clearly not because they cannot access a passive representation for this class of verb.

One possibility is that the representations employed in the production of the passive are different from those employed in its comprehension. For example, although some theorists argue for a system in which shared mechanisms operate on shared representations (e.g., Pickering & Branigan, 1998; Segaert, Menenti, Weber, Petersson, & Hagoort, 2012), few studies

are able to conclusively demonstrate that the mechanisms that operate on syntactic representations within the production and comprehension system are the same. One other possibility is that the differences in behaviour across comprehension and priming tasks actually reflect differences in task demands. The very nature of Maratsos et al.'s task may have meant that the authors did not directly tap into the full extent of children's knowledge of the passive structure; for example, it might be that the children automatically defaulted to an active interpretation, and then subsequently tried to work out the assignment of thematic roles. This might prove too difficult a process for passive sentences with ET verbs where there is no clear change of state to the subject.

Some comprehension tasks encourage children to choose between two competing two-dimensional still scenes. However, depicting an action with an ET verb in a still scene might be difficult for children to interpret. For example in Messenger et al.'s picture-sentence matching task (Experiment 3), target pictures were paired with distractor pictures. Both target and distractor pairs depicted the same action (e.g., *hearing*), but the semantic roles in each picture were different (e.g., target picture = *A mouse is hearing a pirate*; distractor picture = *A pirate is hearing a mouse*). It may be that for ET verbs, such as *hear,* where the subject is not clearly affected, a still image does not provide information to the child about what is happening. In comparison, it might be easier to choose the correct interpretation for a passive sentence with a more prototypically transitive AP verb like *carry* because 'carrying' is a more visually discernible event.

Some tasks do not even provide children with a visual cue. For example, in Maratsos et al.'s study, 4-5 year old children were simply read a sentence (e.g., *Goofy was liked by Donald*), and then asked, "Who did it?". Not only does it seem strange to ask this question when referring to 'liking', but the children were not shown a scene and thus presumably had to construct a mental image of this event in order to successfully answer the question. Here it is entirely possible that children do have an abstract representation of the passive that they can generalise to less transitive ET verbs, but that they found it too difficult to conceptualise the agent and patient of the sentence for these types of verb in the absence of a visual cue.

6.4.2. Conclusion

The current study showed that children's and adults' ability to access a syntactic representation of the passive was not constrained by the prime verb's semantic class in a structural priming task; they were able to generalise across similarly-structured sentences with both ET and TE prime verbs. Furthermore, while knowledge about the verb-structure preferences of verbs from different semantic classes did not influence the priming effect for any of the age groups, 5-6 year olds were more strongly primed by verbs that they had not yet had time to learn. This prime surprisal effect indicates that children's structure choice, at least in the production of the passive, is constrained by how familiar they are with that particular prime verb. These findings support a theory of syntactic development in which the input is considered, and in which there is a close relationship between knowledge of structure and the verb lexicon in both children and adults.

Section 3: Final Discussion

Chapter 7

General Discussion

7.1. Introduction

7.2. Summary of findings

7.3. Theoretical implications

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7.6. Concluding remarks

Chapter 7: General Discussion

7.1. Introduction

The overarching aim of this thesis was to examine the role that the verb plays in the development of syntax. To do this, we used structural priming to investigate the relationship between syntactic structure and the developing verb lexicon. We explored how two lexical effects - verb overlap and verb bias - influence structure choice in children and adults for dative and transitive structures. We also used structural priming to examine how adult syntactic representations are linked to the verb lexicon, and whether this influences the way in which they interpret language. In this chapter, first, we summarise the findings from the studies that explored when and how children's verb-structure links develop, and how these links in adults influence the way in which they interpret language. Next, we discuss how our findings speak to nativist and lexical constructivist theories of syntax acquisition, and what these findings might mean for our understanding of the architecture of the developing and the adult lexicon. We also consider the contribution of the present work to the discussion on what mechanisms might be involved in the development of verb-structure links. We then move on to the limitations and methodological considerations of the present work, before finally suggesting any directions for future research.

7.2. Summary of findings

The aim of chapter 3 was to investigate when and how children (aged 3-4 and 5-6 years) link their knowledge of syntax to their knowledge of how

dative verbs behave in their preferred argument structures. We, first, analysed the Manchester corpus to identify the biases of four familiar alternating dative verbs (study 3a). We then used these verbs in a structural priming paradigm to assess the impact of the lexical boost, target verb bias, and prime surprisal on children's and adults' structure choice (study 3b). The results revealed significant evidence of structural priming in all age groups; both children and adults were more likely to produce a double object dative (DOD) target after a DOD prime compared to after a prepositional object dative (PD) prime. This was taken as evidence that children as young as three have formed an abstract representation of the dative that they use to generalise across similarly-structured sentences with different verbs. The results also showed that, although only adults showed evidence of a lexical boost (i.e., the priming effect was stronger when prime and target sentences shared a verb), both children and adults were sensitive to the identity of the target verb (target verb bias) and the prime verb (prime surprisal). Target verb bias was larger in adults than in children (i.e., adults were more likely than children to produce DOD responses with DOD-biased target verbs), and we interpreted this as evidence that verb-structure links are strengthened as experience of verbs in their preferred structures accumulates. In comparison, prime surprisal was larger in children than adults; for children, priming was stronger when the bias of the prime verb was unexpected in its structure, but for adults this effect was only marginal. Taken together, these findings were interpreted as evidence that children acquire abstract knowledge about structure, and create links between this knowledge and verbs early in the language learning process. We also tentatively suggested that the

development of these links can best be explained by an error-based learning mechanism with a variable learning rate.

Although we attributed the pattern of prime surprisal in chapter 3 to an error-based learning mechanism in which an initial high learning rate leads to large fluctuations in children's verb biases, but smaller changes in those of adults, we also considered an alternate explanation: that adults only showed a marginal effect of prime surprisal because they were too familiar with the verbs in both the DOD and PD structure for them to be surprising in either. The aim of chapter 4, therefore, was to examine whether adults show larger prime surprisal effects with verbs that are less familiar to them.

Chapter 4 used a structural priming paradigm to test whether adults are sensitive to prime surprisal with low frequency biased dative verbs, since verb-structure mismatches with these verbs might be more unexpected than those in chapter 3. The results showed that adults were primed by sentences containing low frequency verbs, and because this effect was stronger for sentences containing DOD-biased verbs, we suggested that this might reflect a difference in the way in which knowledge about these verbs is stored and linked to syntactic representations. Adults were not, however, more strongly primed by sentences in which the bias of the prime verb mismatched the structure in which it appeared. In other words, they showed no evidence of prime surprisal. We considered that, perhaps, adults were not surprised by these sentences because inexperience with these verbs combined with the conflict between the prime verbs' biases and their structure made them difficult to parse.

Using a graded judgement paradigm to examine how acceptable adults found these prime sentences, we found that, as predicted, adults rated some sentences in which verb bias and structure were mismatched lower than some sentences in which verb bias and structure were matched. However, since these ratings did not correlate with the size of the priming effects reported earlier in the chapter, we could not conclude that absence of prime surprisal was due to difficulty in parsing the sentences.

Given this, we considered an alternate explanation for the absence of prime surprisal with low frequency verbs: that the infrequency of these verbs in the input might mean that adults had not had the opportunity to gather enough evidence about their argument structure preferences. As such, these verbs may not have been unexpected in either the DOD or PD structure. The aim of chapter 5, therefore, was to investigate whether adults show prime surprisal with non-alternating verbs - verbs that are highly frequent in one structure but ungrammatical (i.e., non-existent) in the other.

Chapter 5 investigated whether adults are sensitive to prime surprisal with ungrammatical prime sentences containing non-alternating DOD- and PD-only verbs. Since these verbs are grammatical (and thus appear frequently) in one structure, but ungrammatical (and so are rarely experienced) in the other, we might expect adults to find sentences in which there is conflict between the prime verb's identity and its structure unexpected. However, the results indicated that adults were not more strongly primed by ungrammatical sentences with non-alternating verbs. They also revealed that adults were not primed by ungrammatical sentences at all. Even more surprising was that they were not primed by the

grammatical sentences; although they were more likely to produce DOD responses after grammatical DOD prime sentences, this effect did not reach significance. To explore the possibility that the absence of a priming effect with grammatical sentences was the result of encountering both ungrammatical and grammatical primes in the same task, we ran a further structural priming study with a different group of adults, but presented them with the non-alternating verbs only in their grammatical structures. The results showed that adults were significantly more likely to re-use the prime structure when they only encountered non-alternating verbs in their grammatical structure. Our failure to find large prime surprisal effects in chapters 4 and 5 led us to conclusion that the age-related difference in the prime surprisal rates in chapter 3 was real; children showed larger prime surprisal effects than adults.

Chapter 3 to 5 investigated the lexical effects on structural priming with dative sentences. In chapter 6, we moved to a different structure: the transitive. Using a priming paradigm, we explored whether children (aged 5-6 and 9-10 years old) and adults show evidence of structural priming with prime sentences containing experiencer-theme (ET; e.g., *love*) and theme-experiencer (TE; e.g., *frighten*) verbs. We also investigated whether children and adults are sensitive to prime surprisal such that they are more strongly primed by passive primes with ET verbs (which are less compatible with the semantics of the passive, and might therefore be unexpected) than by passive primes with TE verbs. As predicted, we found evidence of abstract structural priming for all age groups. This effect, however, was not dependent on the semantic class of the prime verb. In other words, both

children and adults produced more passive responses after passive primes than after active primes for primes containing both ET and TE verbs. Neither children nor adults were sensitive to prime surprisal such that they were more strongly primed by passive primes containing ET verbs. However, the 5-6 year olds did show a different prime surprisal effect: they were more strongly primed by verbs that they had not yet had the time to learn. Thus, the results suggest that young children's passive representations might be influenced by how familiar they are with certain verbs.

In sum, this thesis has shown that the verb plays an important role in the development of syntax; the frequency with which verbs appear in the input and in their preferred argument structures influences both the language that is produced, and the way in which it is interpreted. We found that, children as young as three have abstract representations of the dative structure that allow them to generalise across similarly-structured sentences, and they have already begun to learn the syntactic preferences of dative verbs. This work is the first to show that this knowledge has the ability to influence their structure choice in a structural priming task. The present work has also indicated that children's knowledge of the passive is not constrained to verbs from certain semantic classes, but that experience with verbs is important for the strengthening of verb-structure links across development. Finally, this work has shown that adults' knowledge about verbs and their argument structure constraints can influence the way in which they interpret language. Although, contrary to previous findings, we did not find reliable evidence that adults are sensitive to prime surprisal with alternating dative verbs (e.g., Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013), conflict

between the identity of a non-alternating dative prime verb and its structure can affect whether the appropriate syntactic representations are activated (because ungrammatical prime sentences did not prime). Thus, this thesis has shown that, for both children and adults, we should posit a close integration between syntactic representations and the verb lexicon. Given this, our findings have theoretical implications for our current understanding of when and how syntactic knowledge develops to become adult-like.

7.3. Theoretical implications

The findings from the present work have indicated that, from the age of 3;0, children have developed abstract knowledge of the dative structure that allows them to generalise across verbs, but that they also store knowledge about verbs and their argument structure preferences. These findings not only have consequences for how we conceptualise the relationship between syntactic structure and the developing lexicon, but they also have implications for the core predictions of nativist and lexicalist constructivist theories of syntax acquisition.

The present work showed that, when presented with prime sentences that use a particular sentence structure, children as young as three will generalise across sentences with different verbs. The fact that priming did not rely on the repetition of verbs across prime and target sentences suggests that, by this age, children do not rely on the comparison between lexical items to generalise across similarly-structured sentences. Instead, it indicates that children at this age have already formed representations that support generalisation across verbs. These findings contradict those of some

of the earlier child priming studies. For instance, Savage, Lieven, Theakston, and Tomasello (2003) only found evidence of abstract structural priming in six-year olds; three-year olds were only primed when there was high lexical overlap between prime and target sentences. In other words, for the youngest children, the presentation of the prime structure was not enough to activate the relevant representations; lexical overlap was important for this process. Shimpi, Gámez, Huttenlocher, and Vasilyeva (2007) also did not find evidence of abstract structural priming in three-year olds. Only when they altered their task so that the children repeated each prime sentence before immediately describing the target pictures did three-year olds re-use the syntax of the prime with different verbs. Our findings are, however, consistent with those of the more recent child priming studies that have shown that children aged three tend to echo the structure of the prime sentences that they have recently encountered. For example, our findings fit with those of Bencini and Valian (2008) who found that three-year olds presented with passives were more likely to produce passive responses compared to those presented with active primes. They are also compatible with results reported by Messenger, Branigan, McLean, and Sorace (2012) who too found that three-year olds produced more passive responses after passive primes than after active primes. Taken together, the present work adds to the growing child priming literature that shows that children as young as three have formed abstract representations that are independent of lexical items.

The fact that the three-year olds in our study were able to activate the appropriate representation to produce dative sentences with different verbs

could be used to support early abstraction accounts of syntax acquisition. These accounts claim that young children are sensitive to the abstract properties of speech from the very beginning of the language learning process (e.g., Valian, 1986), and that initial representations are not built around lexical items. Fundamental to these accounts, is that children are endowed with powerful innate linguistic knowledge, biases, and constraints that help them to limit the number of hypotheses about the language, and that this innate knowledge guides syntax acquisition. Because early abstraction accounts all claim that these biases are present from the outset (or at least, very early in development), a core prediction of these accounts is that evidence of abstract knowledge will be demonstrated from an early age.

Our findings, therefore, could be taken as evidence to support the semantic bootstrapping hypothesis (Pinker, 1984) – an account that argues for the early abstraction of syntax. On this account, children are argued to have innate linking rules that allow them to map certain thematic roles onto syntactic positions. The acquisition of syntactic categories occurs because children combine this innate knowledge with cross-situational observations of real world events.

Our findings might also be considered compatible with the syntactic bootstrapping hypothesis (Fisher, Gertner, Scott, & Yuan, 2010) which proposes that children use both the syntactic structure of sentences and unlearned structure-mapping rules to guide their learning of new verbs and other argument-taking predicates. Like the semantic bootstrapping hypothesis, this account also predicts the early abstraction of syntax, and thus predicts that children will demonstrate that they are operating with

abstract syntactic knowledge from early in development. These theories, however, cannot fully account for the findings reported in our study.

This is because whilst our results do show that children are operating with abstract knowledge from a young age, they cannot be taken as evidence that children have employed innate linguistic biases to acquire this knowledge. Accounts such as the semantic bootstrapping hypothesis and the syntactic bootstrapping hypothesis would, presumably, predict that children as young as three should show abstract priming effects because they have powerful innate or unlearned biases that are co-opted into the language learning mechanism. Research, however, has shown that children as young as 1;7 can use distributional cues to form syntactic categories (Gerken, Wilson, & Lewis, 2005), and that at an even younger age - 12 months - can make use of general-purpose statistical learning and pattern recognition abilities to generalise beyond a learned word order in an artificial grammar (Gómez and Gerken, 1999). Thus, it is plausible that by the age of three, children have experienced enough in the input to exploit these skills to form verb-general representations. As such, theories that argue that innate linguistic knowledge and constraints are necessary for syntax acquisition do not offer a perfectly convincing story as to why and how it is that children demonstrate that they are operating with abstract knowledge from a young age.

The age-related dissociation between structural priming and the lexical boost effects presents a challenge for lexical constructivist theories of syntax acquisition. The fact that three-year olds were able to generalise their knowledge of the dative structure to different verbs is tricky for these

accounts. This is because these theories assume that children's initial representations are not fully abstract, but instead, are item-based schemas that only link together elements with shared lexical features. Representations eventually move from being item-based to being abstract through a process of generalisation and comparison (e.g., Tomasello, 1992; Goldberg, 1999). For example, Tomasello's (1992) verb island hypothesis proposes that children do not have verb-general knowledge from early in acquisition. Children are argued, initially, to create links only between verbs and the predicate structures to which they are related. Having built an inventory of verb-specific categories, they are eventually able to abstract the common features across similar verbs. This allows them to form verb-general schemas. Since this account assumes that syntax acquisition begins on a verb-by-verb basis, the development of abstract knowledge of structure is predicted to be slow and gradual. The usage-based model of syntax acquisition also predicts that children begin with a small number of lexically-based schemas. These are argued to have been rote-learned from the input (Tomasello, 2003). Like the verb island hypothesis, the usage-based model claims that children initially store a number of item-based schemas. Through experience with verbs in their argument structures, and by analogising across the various constructions that they encounter, similarities between schemas, and thus, abstract syntactic categories gradually emerge. Once again, because abstraction relies on children experiencing multiple lexically-based schemas with different items (e.g., *eat dinner, eat biscuit, eat apple*), this process is argued to be slow. As such, lexical constructivist accounts predict that children will not show that they possess abstract syntactic

knowledge early in acquisition (e.g., Akhtar & Tomasello, 1997). This means that these theories can only explain the abstract priming effects that we reported (in children aged three) if they assume that the process of abstraction happens more quickly than has been previously predicted by these accounts.

The age-related sequence of the lexical boost that we reported might also be considered a problem for lexical constructivist accounts. Since these accounts argue that children's early representations are largely built around lexical items, these theories, presumably, would predict that the presence of lexically-based representations should boost the priming effect in children. Contrary to this prediction, we found that adults showed a lexical boost, but that children did not. The immediate interpretation of this finding, when it is viewed in isolation of our other results, is that adults' syntactic representations are more closely linked to verbs than those of children. This clearly goes against the assumptions made by lexical constructivist accounts. However, given that the lexical boost might reflect explicit memory (e.g., Chang, Dell, & Bock, 2006) (and, therefore, might not be a reliable measure of syntactic development), it is important to also consider this finding in the light of the two other lexical effects that we report.

As well as investigating the lexical boost in children and adults, we also explored whether children are sensitive to the identity of the target verb (target verb bias) and the identity of the prime verb (prime surprisal). The results indicated that target verb bias was larger in adults than in children. In other words, adults were more likely than children to produce DOD response with DOD-biased target verbs. We also found that prime surprisal was larger

in children than in adults, in that children were more likely than adults to show stronger priming when the prime verb's bias mismatched its structure. Contrary to what our lexical boost findings suggest, these results indicate that, in fact, children's representations are lexically-influenced; they seem to store knowledge about verbs and how they behave. In other words, children do show lexical effects on structural priming, they just do not seem to show it in the form of a lexical boost. One possible reason for this is that the lexical boost does not reflect syntactic knowledge. This idea has been put forward by Chang et al., who propose that the lexical boost arises as a result of the speaker's explicit awareness of the repetition of lexical items across prime and target sentences. On this account, lexical overlap acts as a cue in the retrieval of the explicit memory of the prime structure. The lexical boost should follow the same trajectory as the development of explicit memory which increases with age (Naito, 1990; Sprondel, Kipp, & Mecklinger, 2011). In this way, the lexical boost should be small (or even absent) in young children and larger in adults. Taken together, these findings suggest that we might attribute the absence of a boost in children to an immature explicit memory. They also indicate that, in support of lexical constructivist accounts, children recognise the distributional regularities of the input to track the frequency with which verbs appear in certain argument structures, and that this influences how their representations are formed and activated.

The findings from the present work have two major implications. First, they indicate that children's early syntactic representations are abstract but are closely linked to their knowledge about how verbs behave; from early in the acquisition process children seem to link their abstract knowledge of

structure to their knowledge of verbs and their syntactic preferences. Second, they suggest that the lexical boost is an unreliable measure of verb-structure links, and that interpreting this effect as reflective of syntactic knowledge could lead us to make incorrect inferences about the relationship between syntactic structure and the verb lexicon.

Not only has the present work shed light on the nature of children's early syntactic representations, it has also provided insight into the relationship between experience and the development of verb-structure links. We have already discussed our findings from chapter 3 which showed that experience with verbs in their preferred argument structure influences structure choice for children and adults. Chapter 6 provides further support for the idea that the frequency with which verbs are encountered in the input affects how representations are formed and activated. We found that 5-6 year olds were primed more strongly by sentences with verbs with which they were less familiar (e.g., *irritate* which is learned at around 9 years old). In comparison, 9-10 year olds and adults showed no such effect – presumably because they are more likely to have had more experience with these verbs, and thus, greater opportunity to strengthen the links between these verbs and their passive representations. We suggested, therefore, that the youngest children were still in the process of building links between these verbs and their representations of the passive because they had less experience with these verbs than did older children and adults. As such, we proposed that verb-structure links are initially weak, but are strengthened over development as experience with these verbs accumulates.

The idea that young speakers are sensitive to the distributional information to which they are exposed, and that their linguistic experience influences their syntactic representations, is not unfamiliar. For example, young children are more likely to adopt a non-canonical word order with verbs that are low frequency compared to verbs that are high frequency (Matthews, Lieven, Theakston, & Tomasello, 2005). Children have also been found to rate ungrammatical sentences as less acceptable when they include low frequency verbs compared to when they include high frequency verbs (Ambridge, Pine, Rowland, & Young, 2008). Taken together, the findings fit well with a theory of syntactic development in which the input is considered, and in which knowledge of structure is closely linked to the verb lexicon (e.g., Chang et al., 2006). They are not, however, consistent with theories in which early syntactic knowledge is adult-like (e.g., Valian, 1986).

In addition to providing insight into when children learn to link their syntactic knowledge to their lexical knowledge, the present work has also allowed us to posit a theory about how these verb-structure links are developed. In study 3b, we proposed two possible mechanisms that could explain the development of verb-structure links: an error-based learning mechanism and an associative learning mechanism. In an error-based learning mechanism, like that instantiated in the Dual-path model (Chang et al., 2006), verb-structure links are built by the same mechanism that learns abstract syntactic structure. These links, therefore, develop in parallel with knowledge of abstract syntactic structure. As such, structural priming, target verb bias, and prime surprisal effects should all be seen from early on. The lexical boost, however, is attributed to a separate explicit memory

mechanism, and should not appear until later in development. An associative learning mechanism also predicts abstract structural priming from early on, but unlike error-based learning, the lexical boost and target verb bias effect stem from the same verb-structure links. As such, these effects should be observed at the same time. Furthermore, because priming is independent of the strength of verb-structure links, we should not expect to see prime surprisal effects if verb-structure links are established via associative learning. We reported effects that best explain the development of verb-structure links in terms of an error-based learning mechanism; although, in chapter 3, three-year olds showed evidence of abstract structural priming and target verb bias, they did not also show a lexical boost as would be predicted by an associative learning account. Consistent with an account of syntactic development that uses error-based learning, however, three-year olds showed abstract structural priming, target verb bias, and prime surprisal effects, but no lexical boost. The fact that children did not show a lexical boost, but did show target verb bias effects is not easily explained by an account of syntactic development that uses an associative learning mechanism. This is because, on this view, target verb bias and the lexical boost stem from the same mechanism: each time a verb is heard with a particular syntactic structure, the link between that verb and that structure is strengthened by a fixed amount. We should, therefore, observe these two effects in parallel. Prime surprisal effects are also not easily explained by an associative learning mechanism, and yet we observed these effects in our youngest participants.

Further support that verb-structure links are developed by means of error-based learning comes from our findings in chapter 6 which showed that for 5-6 year olds, structural priming was weakest for prime verbs acquired early in development and strongest for the verbs acquired later on. In the Dual-path model, material that is less well known is subject to greater learning, and results in stronger priming. Error-based learning can, therefore, account for why the youngest children were primed most strongly by the prime verbs that they knew the least. Taken as a whole, the present work tentatively suggests that verb-structure links are established via an error-based learning mechanism that supports the acquisition of abstract and lexical knowledge from early in development, but that a separate mechanism is needed to explain the lexical boost (Chang et al., 2006).

The present work also contributes to our understanding of the architecture of the adult lexicon. In chapter 5, we showed that adults' knowledge about verbs and their argument structure constraints can influence how they interpret language and whether relevant syntactic representations are activated. We found that adults were not primed by sentences in which non-alternating dative verbs were ungrammatical in their structure (e.g., *The girl explained the boy the mistake*), but that they were primed when these verbs were grammatical in their structure (e.g., *The girl explained the mistake to the boy*). We took this as evidence that the syntactic structure of the prime alone is not enough to activate the relevant DOD and PD representations - the compatibility between prime verb identity and prime structure also matters. Recent work by Ivanova, Pickering, McLean, Costa, and Branigan (2102), however, reported different findings. They presented

adults with ungrammatical DOD sentences with non-alternating verbs and found that they could be primed to produce DOD responses with alternating verbs. As such, they suggested that it is the prime structure, and not the links between this structure and individual verbs, that is important for successful priming. Given that ours and Ivanova et al.'s studies are the only ones (of which we are aware) to have examined structural priming with ungrammatical sentences, we cannot rule out that the disparity between our results is a consequence of differences across the tasks.

The results from chapter 4 also revealed that linguistic experience can influence how syntactic representations are stored; adults rated PD sentences as more acceptable than DOD sentences (regardless of the bias of the verb in that sentence). We suggested that adults might possibly view the PD structure as more variable (since it permits more verbs and argument structures than the DOD structure), and that the asymmetry we observed reflects a difference in the way in which knowledge about the properties of these structures is represented. We also found that adults were primed more strongly by DOD-biased verbs than by PD-biased verbs. We suggested that this asymmetry may indicate a difference in the way in which knowledge about these verbs is stored and linked to syntactic representations; given that the DOD structure accepts fewer verbs and argument structures than the PD, adults might have less experience with DOD-biased verbs. As such, stronger priming effects for DOD-biased verbs could be because adults have weaker links between these verbs and their representation of the dative (i.e., prime surprisal).

Taken together, the findings from chapters 4 and 5 raise some interesting issues – in particular, whether there is a real difference between verbs that are ungrammatical in a structure, and verbs that are grammatical but very rarely appear in the language. According to the Dual-path model, predictions about the next word in a prime sentence are made based on the conditional probabilities between words, and these probabilities are based on a speaker's previous experience with these words. Verbs that are very infrequent in the input (i.e., low frequency verbs) are subject to greater prediction error because the speaker will have little experience about what lexical items tend to follow this word. In the same way, verbs that are ungrammatical in a structure will too be subject to greater prediction error because the speaker will have little experience of that verb in that structure. Thus, an interesting question is whether speakers (both children and adults) treat these situations differently. One possibility is that in situations where speakers, regardless of age, have insufficient experience about how verbs behave, contextual information (i.e., pragmatic and semantic considerations) takes over and this drives prediction about the next word (and thus, structure choice). Another possibility, however, is that, because predictions are specific to an individual's experience, prediction error is the same for verbs that have never been heard before because they are so infrequent in the language (e.g., *lob*), and verbs that have not been heard in a particular structure before because they are ungrammatical (e.g., *donate* in a DOD sentence). In other words, it might be that low-frequency verbs are treated and processed in a similar way to verbs that are ungrammatical in a

structure. This poses an interesting avenue for future research with both child and adult speakers.

In sum, the present work has shown that by the age of 3;0, children have formed abstract representations of structure that allow them to generalise across sentences with different verbs, and that, by this age, they have begun to link their abstract knowledge of structure to their knowledge of verbs and their syntactic preferences. The present work also suggests that the lexical boost is not a reliable measure of verb-structure links, and that investigating the effect of verb bias on structural priming is an effective way of learning about the relationship between syntactic structure and the developing verb lexicon. The findings support both early abstraction and lexical constructivist accounts of syntax acquisition to some degree, but neither approach can fully explain the pattern of children's item-based and abstract syntactic knowledge. This work has also indicated that children aged 5;0 can generalise across passive sentences with different verbs, and that these representations are not constrained to verbs from particular semantic classes. Furthermore, they suggest that the accumulation of experience with transitive verbs is important for the strengthening of links between these verbs and passive representations. Finally, the present work has revealed that conflict between the identity of a non-alternating dative prime verb and its structure can affect whether the appropriate syntactic representations are activated. This suggests that adults' knowledge about verbs and their argument structure constraints influences the way in which they interpret language.

7.4 Limitations and methodological considerations

Although the findings from the work presented in this thesis suggest that, for both children and adults, we should posit a close integration between syntactic representations and the verb lexicon, there are still a number of issues that remain unresolved. In comparison to other research, we did not find reliable evidence that adults are sensitive to prime surprisal with alternating dative verbs (e.g., Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013), neither were we able to replicate the findings reported by Ivanova, Pickering, McLean, Costa, and Branigan (2102), who showed that adults can be primed with ungrammatical sentences. It is important to consider that failure to find these effects might not reflect syntactic knowledge, but could be attributed to limitations and differences in the methodology.

The structural priming paradigm is now well-established, and has been shown to be an effective way of investigating the nature of syntactic representations; a number of studies in the adult literature, and more recently, in the child literature (the present work included) have reported robust and replicable abstract structural priming effects across domains and languages. In comparison, the experimental research on the lexical effects on structural priming is still in its infancy. Pertinent to the present work is that the research on prime surprisal is limited to only a handful of studies, all of which differ in methodology. This makes it difficult to draw firm conclusions about the findings.

The present work indicated that adults were not sensitive to prime surprisal, contradicting the findings from the current available research. For example, Fine and Jaeger (2013) found that prime structures that were more

surprising led to stronger expectations that that same structure would also be used in the target sentence. An important difference between their study and the present work is that theirs was a reanalysis of an earlier comprehension priming study by Thothathiri and Snedeker (2008a). Thothathiri and Snedeker's task differed greatly from the paradigm in the present work; they used a visual world eye-gaze paradigm to examine the comprehension of verb argument ambiguities. They measured the difference in looking time to the potential recipient and the potential theme in DOD and PD sentences during an ambiguous interval (200-600 ms after the onset of the first noun). In contrast, the present work looked at structural priming in production, specifically the proportion of DOD responses that were produced after DOD primes compared to after PD primes. Differences between the dependent measure in Thothathiri and Snedeker's study and the dependent measure in the present work, along with differences in task design make it difficult to compare our findings with the effects reported in Fine and Jaeger's study. For instance, it could be that adults are more sensitive to prime surprisal in language comprehension, or simply that effects in production are smaller (Jaeger and Snider, 2013).

There is only one experimental study (of which we are aware) to have directly investigated prime surprisal in adults and to have found behavioural evidence of this effect: Bernolet and Hartsuiker (2010). However, we could still attribute the disparity between the present work's findings and theirs to differences in task design; they looked at structural priming in written production in Dutch, whereas we looked at structural priming in spoken production in English. It could be that Dutch dative verbs behave differently

to English dative verbs. For example, it is possible that the Dutch dative verbs that Bernolet and Hartsuiker used show a stronger preference for one structure over another than the English dative verbs that we used. If so, Dutch adults might be more likely to be surprised by verb-structure mismatches than English adults.

Taken together, methodological differences in task design between the studies that have reported evidence of prime surprisal in adults make it is difficult to discern whether our findings are reliable. So, while connectionist networks may be able to model prime surprisal effects in adults (Chang, Dell, & Bock, 2006), the behavioural evidence for these effects remains inconclusive.

Differences in task design might also explain why Ivanova et al. (2012) were able to prime adults with ungrammatical DOD sentences with non-alternating verbs, but the present study found no such effect. They presented adults with PD-only verbs and used biased target verbs. In comparison, adults in the present work were presented with DOD- and PD-only prime verbs, and equi-biased target verbs. Since their study is the only one to have examined structural priming with ungrammatical sentences, it is not clear whether our findings are anomalous, or are a reliable reflection of how ungrammatical forms are represented in adults.

In sum, the present work has shown that the structural priming paradigm is an effective measure for investigating the nature of syntactic representations over development. We showed that children and adults can generalise their knowledge of the dative and the transitive to produce

sentences with different verbs. The present work has also shown that examining the lexical effects on priming can be a useful way of tapping in to what knowledge children and adults have about verbs and their syntactic preferences. Nonetheless, the findings have also indicated that more work is needed to better understand whether adults are sensitive to verb-structure mismatches with alternating verbs, and whether ungrammatical forms activate the appropriate syntactic representations.

7.5. Outstanding issues and future directions for research

Although the present work has shown that we can use structural priming to learn about the relationship between syntactic structure and the lexicon in children and adults, a number of questions remain unanswered that should be addressed by future research.

First, it is unclear whether the age-related differences in prime surprisal from study 3b was the consequence of an error-based learning mechanism with a variable learning rate, or whether the adults were too familiar with the verbs in both structures for them to be surprising in either. To address this issue, study 4a explored whether adults show prime surprisal effects with low frequency biased dative verbs, since verb-structure mismatches with verbs that they are less familiar might be more unexpected. Even so, adults were not sensitive to prime surprisal with these verbs. One possible explanation for this is that the verbs were so infrequent in the input, that adults had not had the opportunity to gather enough evidence about their syntactic preferences. We addressed this in study 5a by investigating

whether adults show prime surprisal with non-alternating dative verbs - verbs that are highly frequent (grammatical) in one structure, but very infrequent (ungrammatical) in the other. Once again, adults showed no evidence of prime surprisal. However, they showed no evidence of structural priming either. If presenting non-alternating verbs in an ungrammatical structure does not activate the appropriate syntactic representations that lead to successful priming, then this might not be the most effective way to assess whether adults are sensitive to prime surprisal. Future research should, instead, examine whether adults show prime surprisal with alternating verbs that are highly frequent in one structure and rarely encountered in the other. Importantly, these verbs should be grammatical in both structures. This type of research should allow us to determine whether the effects that have been simulated in connectionist models are observed in real-life tasks with adults.

Second, more studies are needed to investigate whether adults can be primed by ungrammatical sentences since the limited available evidence is conflicting. The findings from the present work suggest that knowledge about the prime structure and the identity of the prime verb influences whether or not the appropriate syntactic representations are activated when adults are presented with ungrammatical sentences. In contrast, Ivanova et al. (2012) suggest that when adults are presented with ungrammatical sentences, only the prime structure is important for the activation of syntactic representations needed for structural priming. Future studies could investigate structures other than the dative. This might give us a broader understanding of how important knowledge about verbs and their argument structure constraints is for the activation of syntactic representations.

Third, it is unclear from the present work whether knowledge about the verb-structure preferences of verbs from different semantic classes influences structural priming for young children. In chapter 6, we investigated whether children and adults would show prime surprisal effects such that they would be more strongly primed by passive prime sentences with experiencer-theme (ET) verbs (because these verbs are less compatible with the semantics of the passive and so might be more unexpected) than by passive sentences with theme-experiencer (TE) verbs. We reported that children and adults were not more strongly primed by ET verbs than TE verbs. However, the average age at which the majority of the TE verbs were learnt was later than the age of the youngest participants. In other words, the verbs that the 5-6 year olds should have found the most expected in the passive, were the verbs with which they had the least experience. This potentially confounded the results, and did not allow us to discern whether the links between ET verbs and passive representations are similar or different in strength to links between TE verbs and passive representations. Future research could address this by investigating whether 5-6 year olds show prime surprisal with ET and TE verbs but should ensure that all verbs are matched for the average age at which they are acquired, and that these verbs match the age of the participants.

Fourth, although the present work has allowed us to investigate the interplay between syntactic and lexical knowledge during comprehension priming tasks, it did not allow us to address directly how the lexicon and grammar might be drawn upon during language production. As far as we are aware, there are not yet any structural priming studies that have shown that

a speaker's spontaneous production of a prime sentence leads them to re-use that structure in their target utterance. In other words, it has not yet been shown that speakers are primed by their own language production, and thus it is not clear whether language production (i.e., structure choice) is lexically or syntactically-driven.

It is logical, however, to conceptualise language comprehension as a necessary pre-cursor to language production. We might, therefore, make the same assumptions about language production as we do about comprehension: that structure choice is driven by a combination of syntactic and lexical features. For example, we can make these assumptions based on connectionist models; in the Dual-path model, a hidden event-semantics (meaning) layer is used to determine the possible structure to be produced (i.e., when a transfer message is processed, this will narrow down the predictions so that only structures that denote this act will be produced), but predictions are also made at the lexical level (i.e., next word prediction). We can also make similar assumptions based on findings from experimental research; children and adults in the current work showed evidence of abstract priming irrespective of the identity of the prime verb, suggesting that activation and subsequent production of the appropriate structures is driven by syntactic knowledge and that speakers can parse immediately without existing lexical entries to drive this choice. However, both children's and adults' responses were influenced by the identity of the prime verb. Thus, according to computational and behavioural research, access to both structural and lexical knowledge is important for structure building. Of course, to make more explicit predictions about the relationship between syntax and

the lexicon during production alone, research that treats production as a construct that is separate from comprehension is still needed.

Finally, the present work has shown that neither early abstraction nor lexical constructivist theories can fully account for the abstract and lexical patterning of children's early syntactic knowledge. Early abstraction accounts like the semantic bootstrapping hypothesis and the syntactic bootstrapping hypothesis can currently account for the demonstration of abstract structural priming effects early in development, but struggle to explain why children's responses in a priming task are influenced by the identity of the prime and the target verb. In comparison, lexical constructivist accounts like the verb island hypothesis and the usage-based model can explain why we see target verb bias and prime surprisal effects early on, but have difficulty explaining why children at this stage are also able to generalise across sentences with different verbs.

Central to early abstraction accounts is that the linguistic input to which children are exposed is not rich enough to allow them to learn the complexities of their language. These accounts, therefore, assume that innate linguistic knowledge and principles are fundamental for the acquisition of abstract syntactic knowledge. The present work, however, has shown that children do pay attention to the input. In particular, they track the frequency with which verbs and certain syntactic structures co-occur, and this influences how their syntactic representations are stored and how they perform in structural priming tasks. Thus, the present works suggests that knowledge about verbs and their structure preferences is important in the development of verb argument structure. Early abstraction accounts need to

make clearer the relative contributions of innate knowledge to the acquisition of syntax, and need to incorporate into their theories an explanation of how this knowledge interacts with the input to build mature linguistic knowledge.

Lexical constructivist accounts already consider the role of the verb as important in the development of syntax, and on these accounts, the ability to recognise the distributional regularities of the input is fundamental for the formation of abstract syntactic categories. These theories, however, do not account for any prior knowledge that children might bring to the language learning process to guide the early acquisition of abstract knowledge. Lexical constructivist theories, therefore, need to explain what knowledge or mechanisms children might have that allow them to generalise across verbs at an age earlier than is currently predicted by these accounts.

The present work, therefore, calls for a testable theory of syntactic development that considers the pattern of children's early item-based and abstract syntactic knowledge. One current contender is the Dual-path model which conceptualises syntactic development in terms of an error-based learning mechanism that supports the early acquisition of both abstract structure and verb-structure links (Chang, Dell, & Bock, 2006). The findings from chapter 3 and 6 have provided experimental evidence to support the predictions made by this account, and are the first to show that knowledge about verb-structure links can affect children's performance in a structural priming task. To be confident that these effects are robust, however, it is important that these findings are replicated. Investigating the lexical effects on structural priming across development should help us to better understand the relationship between syntactic structure and the developing

verb lexicon, making it possible for to posit a theory of syntactic development that reflects children's early abstract and lexically-influenced representations.

7.6. Concluding remarks

The work presented in this thesis focused on the role of the verb in the development of syntax. Using a series of structural priming paradigms, the present work indicated that, for both children and adults, there is a complex relationship between knowledge about syntactic structure and knowledge about verbs; by the age of three, children have already formed abstract representations of the dative structure that allow them to generalise across similarly-structured sentences, but they have also already begun to learn the syntactic preferences of dative verbs. This work is the first to show that this knowledge has the ability to influence their structure choice in a priming task. In addition, the present work has shown that children's representations of the passive are not constrained to transitive verbs from particular semantic classes, but that experience with these verbs is important for the strengthening of verb-structure links across development. The findings also indicate that adults track the frequency with which verbs occur in their syntactic structures, and that this knowledge can affect the way in which syntactic representations are stored and activated. Contrary to previous research, however, adults might not be sensitive to prime surprisal. Finally, the findings provide preliminary support for a theory in which verb-structure links are developed via error-based learning. Future research is needed, however, before we can consider this a plausible mechanism for syntactic development.

To conclude, this thesis has shown that structural priming can be a useful way of examining what syntactic representations are like. This work has gone beyond previous research by using a structural priming paradigm that has allowed us to make predictions about the interplay between syntactic and lexical knowledge in children and adults. The research on the lexical effects on structural priming remains limited, and so more experimental work in both children and adults is needed to determine their reliability. Nonetheless, it is clear that we need a theory of syntactic development that posits a close integration between syntactic representations and the developing verb lexicon.

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Appendices

Appendix A. Parent Consent Form and Information Sheet (Study 3b and 6)

child language study CENTRE
THE UNIVERSITY OF LIVERPOOL
Department of Psychological Sciences
Bedford Street South
LIVERPOOL
L69 7ZA

Dear Parent,

At the Child Language Study Centre, we investigate how children learn to speak their native language. [HEADTEACHER] has been kind enough to allow us to conduct one of our language-learning studies at [SCHOOL].

We are interested in learning how the sentences produced by children are affected by the sentences that they have just heard. It will involve children watching cartoon clips on a laptop computer and taking turns with a PhD researcher to describe what is happening in the cartoon. Please note that this research is not aimed at assessing your child's individual performance, and indeed does NOT produce any score that can be taken as a measure of language ability. In fact, there are no "right" or "wrong" answers in this study. We are simply interested in looking at children as a group. Further details of the study are given on the Information Sheet overleaf.

Children tend to enjoy these studies and are usually eager to participate. However, we require consent from you before your child can take part. Participation is entirely voluntary and you may withdraw your child at any time without having to give a reason, and without detriment to you or your child (if you withdraw your child after the study has begun we will destroy any data already collected). If any child does not want to participate themselves they will not be asked to, even if you have given your consent for your child to participate.

If you are willing for your child to take part in this study, please sign, detach, and return the slip at the bottom of this page to your child's teacher by [DATE].

We do hope that you will be happy for your child to participate.

Many thanks,

Michelle Peter
PhD Researcher

✂.....

Language learning in children and adults: Evidence from the priming paradigm

PARENT/GUARDIAN CONSENT FORM

PLEASE RETURN BY [DATE]

I would like my child to participate in the language-learning study to be conducted at [SCHOOL]. I have read and understood all of the information provided on the information sheet, and have had any outstanding queries answered to my satisfaction.

Please circle as appropriate:

My child speaks more than one language YES/NO

Name of child……..... (BLOCK CAPITALS PLEASE)

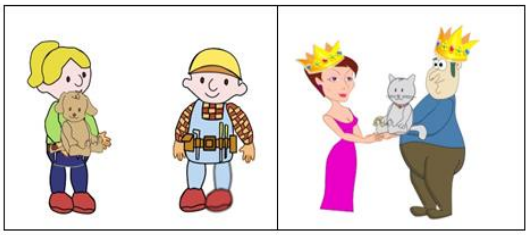
Signed…….....
Date…….....

Language learning in children and adults: Evidence the priming paradigm
Information Sheet

Information about the study

What people say is influenced by what they have just heard others produce. This phenomenon is called PRIMING and affects all aspects of language. Research on priming in adults has told us a lot about how adults understand and produce language. The aim of this study is to study priming in children and to compare what children and adults know about language. In this way, we learn more about how language develops.

Example videos: *"Wendy brought Bob a puppy"* and *"The king gave the queen a cat"*



Your child will take part in a bingo game with one of our researchers. Your child will sit down with researcher in front of a laptop computer that will show short cartoon videos of simple actions (e.g. Dora giving a rabbit to Boots). The researcher and child will take it in turns to describe what is happening in the cartoon to a 2nd researcher. Sometimes, the 2nd researcher will have a card corresponding to that picture and will give this to them in return. The person to fill up their bingo grid first is the winner. Overall, the study takes about twenty minutes per child (usually divided into two 10-minute sessions).

Ethics, confidentiality considerations and parental consent

Children will work with the researchers (a PhD student and an undergraduate student at the University of Liverpool) on a one-to-one basis in the Child Language Lab, a quiet corner of the classroom, the corridor or library area. The researchers involved each have a full "Enhanced Disclosure" Police-check certificate (the same certificate that teachers are now required to obtain). The study requires that children are video/audio recorded. This is in order to ensure that the computer data corresponds with audio data. However, only the researcher involved will have access to the data and the children's names will not be stored with the data. In the write-up of the research, the data will be presented completely anonymously, without referring to individual children. The school will also be sent a summary of the results of the study (again, this will not refer to individual children). Participation is entirely voluntary and you may withdraw a child at any time without having to give a reason and without detriment to you or the child. If any child does not want to participate themselves they will not be asked to, even if you have given your consent for the child to participate.

Reporting complaints and adverse effects

Children tend to enjoy taking part in this study, which has been approved by the University of Liverpool Research Ethics Committee. However, the University has a formal procedure to deal with complaints and for the reporting of adverse effects. If you wish to raise a concern that would be inappropriate to raise with the principal investigator, please use the complaints procedure. Complaints should be addressed to the Research Governance Officer in Research and Business Services (ethics@liv.ac.uk, 0151 794 8727).

Contact Details

For further information on this study, please do not hesitate to contact Michelle Peter by email at Michelle.Peter@liverpool.ac.uk, or Dr Caroline Rowland by email at crowland@liverpool.ac.uk. Further details about the research of the Child Language Study Centre can be found at www.liv.ac.uk/psychology/clrc/clrg.html.
Many thanks for your help.

Michelle Peter
PhD Researcher

Appendix B. Head of Nursery/School Consent Form (Study 3b and 6)

Language learning in children and adults: Evidence from the priming paradigm.

CONSENT FORM

[NAME] Please read the statements below before signing.

*I have read the information outlined in the information sheet.

*I agree to the children in my school taking part in the study outlined in the information sheet.

*The investigator has answered all my outstanding questions about the study and its purpose.

*I understand that I can withdraw from the study at any time. I understand that if I wish to withdraw from the study after taking part, I can request that any data collected from the children at my school be destroyed. However, I understand that this will not be possible if the study has already been submitted for publication.

*I understand that all data will be anonymous and confidential. The children will not be identifiable in any publications. Only the investigators at the Child Language Study Centre of the University of Liverpool will have access to the raw data.

*I understand that, in accordance to the Data Protection Act, I can request access to the data collected.

NAME OF HEAD TEACHER: _____

SIGNATURE:_____ DATE: _____

RESEARCHERS Please read the statements below before signing.

*I agree that the headteacher or parent/guardian can choose to withdraw their child at any time.

*I understand that if the headteacher or parent/guardian wishes to withdraw from the study after taking part, I must destroy all data if they so request it. However, I understand that this will not be possible if the study has already been submitted for publication.

*I agree to keep all data anonymous and confidential and not to allow access to raw data to any investigator outside the Child Language Study Centre at the University of Liverpool.

NAME OF RESEARCHER:

_____

SIGNATURE:_____ DATE: _____

Appendix C. Adult Consent Form (Study 3b, 4a, 4b, 5a, 5b, and 6)

Language Learning in adults
ADULT CONSENT FORM

	Please initial box
1. I confirm that I have read and have understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected.	☐
3. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish.	☐
4. I agree to take part in the above study.	☐

Participant Name: _____Date: _____

Researcher Name: _____Date: _____

The contact details of lead researcher (Principal Investigator) are:

Prof Caroline Rowland, School of Psychology, University of Liverpool, Liverpool, L69 7ZA.

Tel: 0151 794 1120, email: crowland@liverpool.ac.uk

Appendix D. Table to show raw number of PD and DOD utterances in each mother's spontaneous speech to her child for each verb (Study 3a)

Mother of...	Bring		Send		Show		Give		Total
	PD	DOD	PD	DOD	PD	DOD	PD	DOD	
Alice	12	6	3	0	1	19	8	58	66
Billy	16	4	2	4	6	21	13	65	78
Bob	5	3	0	0	2	8	19	89	108
Helen	0	2	4	0	2	11	16	35	51
Ivy	5	4	0	2	0	19	25	71	96
Jack	2	0	2	1	1	10	11	69	80
Lucy	2	1	2	0	4	2	40	51	91
Mary	4	2	4	2	7	14	13	164	177
Olga	9	2	1	0	1	23	18	106	124
Rebecca	7	0	4	1	3	15	18	60	78
Sid	2	0	3	1	0	8	6	28	34
Steve	8	5	4	1	2	2	35	51	86
Total	**72**	**29**	**29**	**12**	**29**	**152**	**222**	**847**	**1069**

Appendix E. Sentence stimuli (Study 3b)

Test items

Prime sentences before the slash are presented in the DOD structure; those after the slash are in the PD structure. The four prime verbs are given in parentheses. Target stems used the same combination of agent, verb, recipient, and theme as prime sentences (e.g., the target stem, "*Piglet GAVE*..." was designed to elicit either *Piglet gave Tigger a puppy* or *Piglet gave a puppy to Tigger*).

1. The king (GAVE/ SHOWED/ BROUGHT/ SENT) the queen a baby/ a baby to the queen
2. The boy (GAVE/ SHOWED/ BROUGHT/ SENT) the girl a fish/ a fish to the girl
3. Wendy (GAVE/ SHOWED/ BROUGHT/ SENT) Bob a puppy/ a puppy to Bob
4. Dora (GAVE/ SHOWED/ BROUGHT/ SENT) Boots a rabbit/ a rabbit to Boots
5. The prince (GAVE/ SHOWED/ BROUGHT/ SENT) the princess a baby/ a baby to the princess
6. The king (GAVE/ SHOWED/ BROUGHT/ SENT) the queen a cat/ a cat to the queen
7. Piglet (GAVE/ SHOWED/ BROUGHT/ SENT) Tigger a puppy/ a puppy to Tigger
8. Wendy (GAVE/ SHOWED/ BROUGHT/ SENT) Bob a rabbit/ a rabbit to Bob

Filler items

1. Boots was flying
2. The princess jumped
3. Piglet and Tigger bounced
4. The king and queen waved
5. Tigger was washing
6. The prince was rocking
7. Piglet waved
8. The cat was swinging
9. Dora was flying
10. Bob was swinging
11. The princess and the cat were rocking
12. Dora and Boots waved
13. Bob was flying
14. The prince jumped
15. Tigger was rocking
16. The queen waved
17. The king and queen bounced
18. Piglet jumped
19. Wendy was flying
20. Dora was washing
21. The boy waved
22. Boots pointed at Dora
23. Wendy and Bob jumped
24. Dora was swinging
25. The girl waved
26. Wendy pointed at Bob
27. Boots was washing
28. Piglet was rocking
29. The cat bounced
30. Bob jumped
31. Boots waved at Dora and the baby
32. The king pointed at the queen

Appendix F. Sentence stimuli (Study 4a)

Prime sentences before the slash are presented in the DOD structure; those after the slash are in the PD structure.

Test items
DOD-biased prime verbs

1. The maid PROMISED the king a gift/ a gift to the king
2. The man PROMISED the woman a ring/ a ring to the woman
3. The queen AWARDED the soldier a medal/ a medal to the soldier
4. The teacher AWARDED the girl a prize/ a prize to the girl
5. The farmer CHUCKED the rabbit a carrot/ a carrot to the rabbit
6. The woman CHUCKED the builder a ball/ a ball to the builder
7. The fire-fighter LOANED the maid a mop/ a mop to the maid
8. The boy LOANED the chef a pencil/ a pencil to the chef
9. The nurse READ the policeman a book/ a book to the policeman
10. The girl READ the man a letter/ a letter to the man
11. The chef SERVED the doctor a meal/ a meal to the doctor
12. The waitress SERVED the boy a cake/ a cake to the boy

PD-biased prime verbs

1. The builder FLUNG the farmer a bottle/ a bottle to the farmer
2. The boy FLUNG the squirrel an acorn/ an acorn to the squirrel
3. The librarian ISSUED the boy a fine/ a fine to the boy
4. The policeman ISSUED the maid a ticket/ a ticket to the maid
5. The doctor WROTE the woman a letter/ a letter to the woman
6. The maid WROTE the queen a note/ a note to the queen
7. The king POSTED the man a card/ a card to the man
8. The woman POSTED the fire-fighter a gift/ a gift to the fire-fighter
9. The soldier LOBBED the girl a bomb/ a bomb to the girl
10. The man LOBBED the clown a book/ a book to the clown
11. The horse KICKED the nurse a ball/ a ball to the nurse
12. The girl KICKED the teacher a box/ a box to the teacher

Appendix G. Example of acceptability rating sheet: practice session and first page of test session (Study 4b)

Participant number: ……..……...

PRACTICE SESSION

a The queen was impressed by the maid

b The boy nailed the wall with posters

c The city was surrounded by hills

d The policeman spilt the rug with juice

e The man tumbled the books off the table

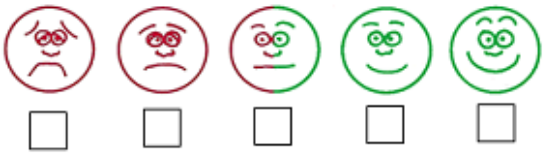
f The teacher filled paper into the box

g The sailor covered salt onto his dinner

TEST SESSION

1 The maid promised the king a gift

2 The nurse stained blood onto her shirt



3 The soldier lobbed the girl a bomb

4 The woman coated the teacher with mud

5 The king posted a card to the man

6 The boy crowded people into the room

Appendix H. Sentence stimuli (Study 5a)

Prime sentences before the slash are presented in the DOD structure; those after the slash are in the PD structure.

Test items
DOD-only prime verbs

1. Homer BET Marge a chocolate bar/ a chocolate bar to Marge
2. The doctor BET the waitress £5.00/ £5.00 to the waitress
3. Homer SAVED Marge £10/ £10 to Marge
4. The nurse SAVED the builder £5.00/ £5.00 to the builder
5. Marge REFUSED Homer a beer/ a beer to Homer
6. The doctor REFUSED the waitress the medicine/ the medicine to the waitress
7. Bart DENIED Lisa a drink/ a drink to Lisa
8. The girl DENIED the soldier a meal/ a meal to the soldier
9. The dog COST Lisa £10/ £10 to Lisa
10. The rabbit COST the maid £20/ £20 to the maid

PD-only prime verbs

1. Marge PULLED Homer a chest/ a chest to Homer
2. The boy PULLED the chef a box/ a box to the chef
3. Marge CARRIED Homer a bucket/ a bucket to Homer
4. The waitress CARRIED the doctor a cake/ a cake to the doctor
5. Homer LIFTED Marge a tyre/ a tyre to Marge
6. The builder LIFTED the nurse a crate/ a crate to the nurse
7. Lisa SHOUTED Bart a message/ a message to Bart
8. The soldier SHOUTED the girl an order/ an order to the girl
9. Bart WHISPERED Lisa a secret/ a secret to Lisa
10. The policeman WHSIPERED the maid a story/ a story to the maid
11. Lisa EXPLAINED Bart the homework/ the homework to Bart
12. The girl EXPLAINED the boy the mistake/ the mistake to the boy
13. Bart ANNOUNCED Lisa the news/ the news to Lisa
14. The chef ANNOUNCED the boy the instructions/ the instructions to the boy

Appendix I. Sentence stimuli (Study 5b)

Prime sentences before the slash are presented in the passive structure; those after the slash are in the active structure.

PD-only verbs – presented only in the PD structure

1. The chef CARRIED a meal to the doctor
2. The policeman WHISPERED a story to the maid
3. Lisa EXPLAINED the homework to Bart

PD-biased verbs – presented only in the DOD structure

1. The queen BROUGHT the soldier a medal
2. The chef SOLD the queen an ice-cream
3. Marge TOOK Homer a bucket

DOD-only verbs – presented only in the DOD structure

1. Homer BET Marge a chocolate bar
2. The girl DENIED the soldier a meal
3. The dog COST Lisa £10

DOD-biased verbs – presented only in the PD structure

1. The waitress GAVE the doctor a cake
2. The maid SHOWED the policeman £10
3. Homer OFFERED Marge a tyre

Equi-biased verbs – presented in both the DOD (before the slash) and PD structure (after the slash).

1. Bart THREW Lisa a ball/ a ball to Lisa
2. The nurse FED the horse an apple/ an apple to the horse
3. Marge PASSED Homer a balloon/ a balloon to Homer
4. The man TOSSED the dog a bone/a bone to the dog
5. Homer OFFERED Marge a tyre/ a tyre to Marge
6. The girl FAXED the king a picture/ a picture to the king
7. The maid SLIPPED the man a note/ a note to the man

Appendix J. Sentence stimuli (Study 6)

Prime sentences before the slash are presented in the passive structure; those after the slash are in the active structure.

Test items
Experiencer-theme verbs

1. Bart was LIKED by Lisa/ Lisa LIKED Bart
2. The girl was LIKED by the boy/ The boy LIKED the girl
3. The king was BELIEVED by the queen/ The queen BELIEVED the king
4. Marge was BELIEVED by Homer/ Homer BELIEVED Marge
5. Wendy was HEARD by Bob/ Bob HEARD Wendy
6. The prince was HEARD by the princess/ The princess heard the prince
7. Marge was REMEMBERED by Homer/ Homer REMEMBERED Marge
8. The boy was REMEMBERED by the girl/ The girl REMEMBERED the boy
9. Bart was LISTENED TO by Lisa/ Lisa LISTENED TO Bart
10. The girl was LISTENED TO by the boy/ The boy LISTENED to the girl
11. Marge was UNDERSTOOD by HOMER/ Homer UNDERSTOOD Marge
12. The king was UNDERSTOOD by the queen/ The queen UNDERSTOOD the king
13. Wendy was LOVED by Bob/ Bob LOVED Wendy
14. The princess was LOVED by the prince/ the prince LOVED the princess
15. Marge was WATCHED by Homer/ Homer watched Marge
16. The boy was WATCHED by the girl/ The girl watched the boy

Theme-Experiencer verbs

1. Lisa was DISTRACTED by Bart/ Bart DISTRACTED Lisa
2. The boy was DISTRACTED by the girl/ The girl DISTRACTED the boy
3. Homer was SURPRISED by Marge/ Marge SURPRISED Homer
4. The queen was SURPRISED by the king/ The king SURPRISED the queen
5. Bob was SHOCKED by Wendy/ Wendy SHOCKED Bob
6. The princess was SHOCKED by the prince/ The prince SHOCKED the princess
7. Lisa was ANNOYED by Bart/ Bart ANNOYED Lisa
8. The boy was ANNOYED by the girl/ The girl ANNOYED the boy
9. Homer was IRRITATED by Marge/ Marge IRRITATED Homer
10. The girl was IRRITATED by the boy/ The boy IRRITATED the girl
11. Homer was TEASED by Marge/ Marge TEASED Homer
12. The queen was TEASED by the king/ the king TEASED the queen
13. Bob was STARTLED by Wendy/ Wendy STARTLED Bob

14. The princess was STARTLED by the prince/ The prince STARTLED the prince
15. Homer was DISTURBED by Marge/ Marge DISTURBED Homer
16. The girl was DISTURBED by the boy/ The boy DISTURBED the girl

Appendix K. Mean (SD) age of acquisition of the prime and target verbs taken from Kuperman, Stadthagen-Gonzalez and Brysbaert (2012) (Study 6)

Verb type	Mean age of acquisition (SD)
Experiencer-theme prime verbs	
like	3.68 (1.89)
hear	3.80 (1.64)
watch	4.33 (1.61)
love	5.17 (3.54)
listen	5.40 (2.62)
remember	5.63 (1.95)
believe	5.78 (1.70)
understand	6.17 (2.75)
Theme-experiencer prime verbs	
tease	5.11 (1.41)
surprise	5.47 (2.01)
annoy	7.22 (2.05)
shock	7.53 (2.32)
disturb	8.22 (3.37)
distract	8.72 (4.16)
startle	9.17 (2.50)
irritate	9.47 (4.01)
Agent-patient target verbs	
hug	2.58 (0.96)
hold	4.67 (2.89)
call	4.74 (1.85)
pat	5.07 (2.12)
chase	5.53 (2.12)
lead	6.76 (3.42)
squash	6.94 (3.30)
avoid	8.50 (2.95)