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Sentence processing in aphasic speakers with short-term memory deficits: Interactions between structural and lexical processing

by

Hao Yan

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APPROVED, THESIS COMMITTEE

Dr. Randi Martin, Chair,
Elma Schneider Professor of Psychology,
Department of Psychology

Dr. Simon Fischer-Baum, Assistant Professor, Department of Psychology

Dr. Robert Englebretson, Associate Professor, Department of Linguistics

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Abstract

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The current research investigates interactions between lexical and structural processing in the construction and interpretation of transitive and dative sentence structures, and relates speakers’ choice of structure in sentence production to STM processes and recent/long-term language experience conditioned on lexical information. Study 1 investigated whether STM is related to the increased tendency for speakers to reuse a structure when the verb is also repeated. Speakers show syntactic priming – that is, a tendency to repeat syntactic constructions they have recently comprehended or produced – and this tendency is even stronger when adjacent utterances share the same main verb, termed the lexical boost. Some have suggested that abstract syntactic priming (i.e., with no lexical overlap) derives from implicit learning, whereas the lexical boost derives from explicit short-term memory (STM) for the prime (e.g., Chang, Dell, & Bock, 2006). To address this issue, Experiment 1.1 assessed twelve aphasic patients with varying degrees of STM deficits and eleven age-matched healthy control speakers in a syntactic priming experiment using a picture description paradigm. Experiment 1.2 assessed eight patients and ten control speakers in another syntactic priming task using written word arrays for target trials. Despite patients’ difficulty in maintaining phonological, semantic, and structural
information, as evidenced by various STM and sentence repetition measures, most of
them showed lexical boost effects comparable to those of healthy speakers. Moreover, the
size of the lexical boost was unrelated to the degree of STM deficit, suggesting that the
lexical boost does not rely on explicit memory. Alternative explanations for the differing
patterns for syntactic priming with and without lexical overlap are discussed.

Compared to young speakers, many patients and some older control speakers had
very limited production of double object (DO) dative sentences in the picture description
task in Experiment 1.1 and predominantly produced prepositional dative (PD) sentences.
Study 2 included four experiments to explore factors behind the choice of structure in
dative sentence production. There are various possible accounts of speakers’ preference
for the PD structure over the DO structure. DO could be syntactically more complex
(Chomsky, 1975; Beck & Johnson, 2004), or more difficult to parse without explicit
markers of grammatical/thematic roles of post-verbal nouns (Stowell, 1981). The word
order in DO could be different from a default order of conceptual planning, which plans
the verb and the theme together, before a recipient (O’Grady & Lee, 2005). Accessibility
of nouns after the verb may also affect word order and the choice of structure in dative
sentence production (Bresnan, Cueni, Nikitina, & Baayen, 2007). In accordance with
these hypotheses, the factors investigated included syntactic complexity (DO vs. PD),
function word processing (functions of prepositions in dative sentences), semantic factors
(ease of semantic integration between the verb and the theme), processing factors
(accessibility of the recipient), as well as the relation between these factors and STM
capacities. In a sentence repetition task, Study 2.1a found that DO sentences were more
difficult to repeat than PD sentences for patients, and this structural effect was related to
percent DO production in Experiment 1.1. Pronoun recipients facilitated repetition of DO sentences, and easy semantic integration between the verb and the theme improved repetition of PD sentences. A grammaticality judgment task in Study 2.1b found some evidence for a weak pronoun recipient effect, but not a semantic integration effect. Only a small structural effect was found, which was not related to percent DO production in Experiment 1.1, suggesting that the limited DO production was not caused by any potential weakness in the syntactic knowledge of the DO structure. Study 2.1c found limited evidence for a structural effect in a sentence anomaly judgment task, and some evidence that prepositions in PD sentences and provide-with sentences serve as explicit markers of grammatical functions to facilitate parsing of post-verbal objects. Finally, Study 2.2 found that both patient and control speakers were more likely to choose the DO structure in picture description when using pronoun recipients or more accessible full NP recipients, reflecting a tendency to produce the more accessible word earlier in a sentence. This accessibility effect and the pronoun recipient in Experiment 2.1a and 2.2 were consistent with findings in corpus studies that a DO structure with a pronoun recipient is a highly frequent dative construction (Bresnan, Cueni, Nikitina, & Baayen, 2007), suggesting an important role of language experience in sentence processing. Importantly, STM capacities were related to percent DO production in Experiments 1.1, 1.2, and 2.2, and the structural effect in dative sentence repetition in Experiment 2.1a, indicating that the processing difficulty with DO sentences is related to STM costs. Taken together, these findings in Study 1 and 2 support a multi-factorial, usage-based account of sentence processing (Gahl & Menn, 2016; Menn & Bastiaanse, 2016), which is achieved via the
interactions between structural processing and lexical processing, with the potential support of STM resources for some aspects of these processes.
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Sentence processing in aphasic speakers

with short-term memory deficits:

Interactions between structural and lexical processing

Overview

Producing a sentence requires the retrieval of both structural (i.e., grammatical) information and lexical (i.e., word) information from the speaker’s mind. While this may sound simple, a number of factors become involved in the choice of lexical items and structures and their integration. For example, in describing a scene of a dog chewing a bone, speakers need to retrieve from lexical representations words referring to objects and actions in the scene – “dog,” “chew” and “bone”; they also need to consult their grammatical representation to decide on the structure of the sentence: in this case, either an active sentence (e.g. *the dog chewed the bone*) or a passive one (e.g. *the bone was chewed by the dog*). This seems to be complicated enough, but speakers also need to choose the right tense and make proper inflections before speaking them. One central issue concerning the nature of sentence processing is the relationship between structural knowledge/processing and lexical knowledge/processing (Bock & Ferreira, 2014). Is structural processing an autonomous process independent of lexical processing? Or are structural representations closely associated with the mental lexicon (i.e., our storehouse of knowledge about words)? If structural knowledge and lexical knowledge processing
are two highly-interacting systems, how would this interaction be affected by experience of language use and short-term memory (STM) processes?

My dissertation studies the interaction between structural processing and lexical processing by studying sentence processing in aphasic patients with varying degrees of short-term memory deficits. Study 1 explored if processing of a repeated lexical item (specifically, the verb) affected patients’ tendency to repeat a previous syntactic structure in sentence production, even though they might have difficulty explicitly remembering the repeated word. Study 2 investigated how lexical processing, structural processing, and STM constraints influenced patients’ production of double object dative constructions relative to prepositional datives.

Specifically, two experiments in Study 1 of my dissertation aimed to test if the lexical boost (i.e., the increase in syntactic priming with lexical overlap between prime and target; Pickering & Branigan, 1998) is an automatic interactional effect of structural and lexical processing (e.g., Pickering & Branigan, 1998), or a by-product of explicit STM processes (e.g., Chang, Dell & Bock, 2006). The aphasic patients in my dissertation research varied considerably in their STM capacities at different levels, with some of them having difficulties in maintaining even one or two words in mind, thus making it possible to assess whether the lexical boost effects were related to their explicit STM capacities, as some have argued that the lexical boost depends on explicit remembering of information in the prime sentence (Chang et al., 2006; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008). If no such relation is obtained, the results would provide valuable evidence addressing the automaticity of the interaction between lexical and structural processing.
Study 2 aimed to explore the structural, lexical, and STM factors underlying the choice of structure during dative sentence production. Many aphasic patients and some control subjects in Study 1 produced a very limited proportion of double object (DO) sentences (e.g. the student sent the businessman a bag), instead producing the majority of dative sentences in the prepositional dative (PD) structure (e.g. the student sent a bag to the businessman). This seemed surprising because previous findings from corpora of natural English language showed that DO sentences are more frequent in modern English than prepositional dative sentences (Bresnan et al., 2007; Gries, 2005), though this greater frequency is conditioned on whether the recipient is a pronoun or full noun. With pronoun recipients, the two structures are approximately equal in frequency. The difficulty with double object sentences could potentially be related to syntactic factors (greater complexity of DO), semantic factors (mapping between the event structure and the syntactic structure, and semantic integration of the verb and post-verbal nouns), processing factors related to accessibility of post-verbal nouns, as well as the relation between these factors and STM deficits. Experiments 2.1 and 2.2 explored all these factors in various tasks that tapped different levels/modalities of sentence processing. Specifically, Experiment 2.1a investigated effects of pronoun recipient and semantic integration on dative sentence repetition. Experiment 2.1b used a grammatical judgment task to assess patients’ grammatical processing abilities of dative sentences. Experiment 2.1c used a sentence anomaly judgment task to explore the function of “to” as a grammatical marker in parsing the PD structure. Experiment 2.2 encouraged the use of pronoun recipients to explore effects of accessibility and construction frequency on the choice of dative structure in sentence production. Although the major purpose was to
investigate factors affecting the choice of structure in sentence production, under the guiding assumption of shared syntax between processing modalities (e.g., Macdonald, 2013; Menenti, Gierhan, Segaert, & Hagoort, 2011; Pickering & Garrod, 2013), tasks that mainly involved comprehension (Experiments 2.1b and c) explored factors that could be relevant to sentence production but were difficult to manipulate in production tasks. The current research from Studies 1 and 2 aimed to provide valuable evidence to better understand interactions of various linguistic and cognitive factors in human sentence processing.
Study 1

Lexical overlap increases syntactic priming in aphasic patients independently of short-term memory abilities: Evidence against the explicit memory account of the lexical boost

Introduction

Speakers in a conversation align along multiple dimensions (Pickering & Garrod, 2004). They converge on speech rate (Giles, Coupland, & Coupland, 1991), on the use of lexical items (Garrod & Anderson, 1987), and even on the use of syntactic structures (Bock, 1986). This last type of alignment is termed structural or syntactic priming, and refers to the tendency of speakers (and also signers) to repeat or more quickly process a sentence structure that they have recently comprehended or produced (Bock, 1986; Corley & Scheepers, 2002; Hall, Ferreira, & Mayberry, 2015). For example, a speaker who recently produced or perceived an active sentence structure like one of the fans punched the referee tends to describe a subsequent picture with an active sentence such as the lightning struck the church. By comparison, having produced or perceived a passive sentence like the referee was punched by one of the fans, the speaker is more likely to reuse the passive structure for a subsequent picture, producing a sentence like the church was struck by the lightning (Bock, 1986; for a comprehensive review of syntactic priming studies, see Pickering & Ferreira, 2008). Moreover, the tendency to reuse a structure is increased if the verb in the prime sentence matches that in the target sentence (e.g., the

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1 Dr. L. Robert Slevc of the University of Maryland contributed to this research, providing stimulus materials and aiding in the interpretation of results.
passive will be more likely for the prime *the referee was punched by one of the fans* if the action in the target sentence is *punching* as well – e.g., *the guard was punched by the hiker* (e.g., Hall et al., 2015; Pickering & Branigan, 1998). This increased priming is termed the lexical boost.

The exact mechanisms underlying syntactic priming and the lexical boost are not yet clear. By a lexicalist account (Pickering & Branigan, 1998), syntactic priming reflects residual activation of combinatorial units and their pairings with specific verbs. This suggestion is plausible because the lemma of the verb is associated with syntactic information such as number, tense and person (e.g., Levelt, Roelofs, & Meyer, 1999), so the verb lemma might also be linked to syntactic structures, termed combinatorial nodes by Pickering and Branigan (1998). For example, the combinatorial node for a prepositional dative sentence (PD) can be represented as [NP-V-NP-PP], and the combinatorial node for a double object sentence (DO) is [NP-V-NP-NP]. Processing a sentence activates the verb and its associated combinatorial node, and the residual activation of the combinatorial node primes the subsequent processing of the same sentence structure.

The lexicalist account also provides a means of accounting for the lexical boost. According to the lexicalist account processing a PD like *the ballerina mailed a letter to the professor* not only activates the combinatorial node [NP-PP] but also the *mail* lemma and the link between the lemma node of *mail* and the combinatorial node. Therefore, if a later sentence contains the same verb *mail*, it will not only be primed by the residual activation of the combinatorial node, but also by the residual activation of the lemma node and the lemma-structure connection, resulting in an enhanced priming effect, i.e.,
the lexical boost effect. In this view, the lexical boost results from the repetition of
critical content words between prime and target like the main verb (Pickering & Branigan,
1998). Priming can also result from the overlap in the head noun of complex noun
phrases. (e.g., the white sheep vs. the sheep that is white; Cleland & Pickering, 2003).
However, syntactic priming seems to be unaffected by overlap in function words like *to*
(Bock, 1989) or *that* (Ferreira, 2003b), or in inflectional affixes (Pickering & Branigan,
1998). This might be explained on the grounds that function words are selected *after* the
construction of the sentence structure, and are therefore not able to influence the choice
of structure (Pickering and Ferreira, 2008). Fitting with a transient activation account, the
lexical boost in syntactic priming effect appears to be relatively short lived (e.g.,
Branigan, Pickering, & Cleland, 1999; Hartsuiker, Bernolet, Schoonbaert, Speybroeck, &
Vanderelst, 2008).

However, a significant challenge to the lexicalist account (and to any other
explanation of syntactic priming that relies on transient activation) is that syntactic
priming effects without lexical overlap can be quite long-lived. Syntactic priming can
persist across many intervening sentences (Bock, Dell, Chang, & Onishi, 2007; Bock &
Griffin, 2000; Branigan & McLean, 2016; Hartsuiker et al., 2008) and across
experimental sessions spanning at least a week (Kaschak, Kutta, & Schatschneider,
2011c). This long-lived priming appears not to depend on any explicit memory for the
prime as it even emerges, despite up to ten intervening trials, in amnesic patients without
the ability to explicitly recall prime sentences (Ferreira, Bock, Wilson, & Cohen, 2008).
A related finding is the cumulative priming effect. Kaschak (2007) found that
manipulating the proportion of a specific dative structure in a large block of trials (in the
context of 76 fillers, 20 prime sentences that were all DOs, half DOs and half PDs, or all PDs) affected the base rates of structures that they later produced in a testing phase, showing long-lasting priming. One notable exception that challenged the persistent priming effect was a recent study by Bernolet, Collina, and Hartsuiker (2016), which found that syntactic priming effects decay from Lag 0 to Lags 2 and 6, though some evidence for long-term cumulative syntactic priming was also found in the same study in that the proportion of alternative structures that were produced was influenced by the number of those structures produced or comprehended by the participant across the entire experiment (rather than in terms of lag).

These findings on persistence have led to accounts of syntactic priming that rely on implicit learning processes (Chang, Dell, & Bock, 2006; Chang & Fitz, 2014; Ferreira & Bock, 2006; Jaeger & Snider, 2013). By Chang et al. (2006)’s account, syntactic priming reflects implicit learning of the mapping between the message and the sentence structure. For example, a typical dative sentence expresses an event in which an agent transfers a theme to a recipient. This event can either be described in a DO sentence, in which the recipient precedes the theme in the surface sentence structure, or in a PD sentence, in which the recipient is put in a prepositional phrase that comes after the theme. Having processed a DO sentence permanently strengthened the connection between the dative event message and the DO structure through an error-driven learning mechanism, so that the next time when a similar event is encountered, the speaker is more likely to describe it with a DO structure. In this view, lexical retrieval does not play a central role in syntactic construction, and sentence production depends on an abstract structural process that is not heavily dependent on lexical knowledge (Konopka & Bock, 2009).
An elegant feature of these implicit learning accounts is that syntactic priming can be explained as simply a case of more general learning processes. However, while long-lived syntactic priming effects have been observed, the lexical boost effect appears to be much more transient, thus providing a challenge to an implicit learning account for all aspects of priming (e.g., Pickering & Branigan, 1998). For example, Branigan et al. (1999) found that when the prime and the target shared the same verb, the syntactic priming effect diminished with four intervening filler sentences (c.f. Branigan, Pickering, Stewart, & McLean, 2000). The lexical boost effect for three- to four-year-old children and control adult speakers decayed with two intervening filler sentences (Branigan & McLean, 2016). Similarly, Hartsuiker et al. (2008) found that lexically-independent priming effects persisted across multiple intervening sentences, but that the lexical boost decayed with only minimal intervening items, in both spoken and written production (but see Bernolet et al., 2016 for decaying syntactic priming over lags).

This distinction between long-lived priming of “abstract” (not lexically dependent) structure and the short-lived lexical boost suggests that syntactic priming might reflect two separate processes: an implicit abstract syntactic priming effect and a lexical boost that is subserved by explicit memory for the word string in the prime (Chang et al., 2006; Ferreira & Bock, 2006; Hartsuiker et al., 2008; Reitter, Keller, & Moore, 2011). Such a dual-locus account of syntactic priming accounts for the different time courses of these two effects. Various lines of evidence suggest that the long-lived abstract priming effect is indeed an implicit effect; for example, biasing participants toward the production of less frequent structures results in stronger cumulative priming effects than biasing participants toward the more frequent structures, termed the inverse frequency effect or
inverse preference effect (Bernolet & Hartsuiker, 2010; Ferreira, 2003b; Hartsuiker, Kolk, & Huiskamp, 1999; Hartsuiker & Westenberg, 2000; Kaschak, Kutta, & Jones, 2011b; Saffran & Martin, 1997; Scheepers, 2003). This finding is in accordance with the assumption of the error-based learning mechanism that the language system learns more about less frequent structures (Chang et al., 2006; Chang, Janciauskas, & Fitz, 2012). Abstract priming effects are also unrelated to how well speakers explicitly remember the prime (Bock & Griffin, 2000). As noted earlier, even anterograde amnesia patients, with very poor explicit memory for primes, show a persistent syntactic priming effect comparable to that of control speakers (Ferreira et al., 2008). In addition, they may show even stronger syntactic priming than control speakers (Heyselaar, Segaert, Walvoort, Kessels, & Hagoort, 2017)².

In contrast, the short-lived lexical boost is typically construed as a non-automatic effect reflecting explicit memory for the prime. That is, the repeated verb serves as a retrieval cue that makes the speakers more likely to recall from their explicit short-term memory (STM) the surface structure of the prime which makes it highly available for reuse (Chang et al., 2006; Ferreira & Bock, 2006; Hartsuiker et al., 2008). A computational instantiation of these notions using the ACT-R architecture (Anderson et al., 2004) has been provided by Reitter et al. (2011), in which long-term priming effects result from both long-term base-level implicit learning and short-term spreading activation of the syntactic structure, and the lexical boost results from the retrieval of the

² Bernolet et al. (2016) suggested that although long-term syntactic priming effect is based on implicit learning, explicit memory boosted syntactic priming in the short term. The conclusion was largely based on the results that both syntactic priming and participants’ ability to recall the prime structure decayed with intervening trials, but this study does not provide any direct evidence about the role of short-term memory in syntactic priming.
sentence structures driven by the repeated lexical item stored in the STM buffer. Another approach that also assumes both residual activation of linguistic representations and implicit learning of syntactic structures has been proposed by Tooley and colleagues (Tooley & Bock, 2014; Tooley & Traxler, 2010; Traxler & Tooley, 2008; Traxler, Tooley, & Pickering, 2014). According to this model, the short-term lexical boost and syntactic priming between adjacent sentences result from transient residual activation of the lemma, the syntactic structure, and the connection between them, as in Pickering and Branigan (1998). In addition, however, implicit learning can change the representational strength of the combinatorial node per se (independent of its connection to particular lexical items) and cause the long-term syntactic priming effect. Therefore, this model assumes that while the lexical boost is a short-term effect, syntactic priming has both short-lived and long-term components (see also Branigan & McLean, 2016). This approach is consistent with (Bernolet et al., 2016) recent findings of both decay of abstract priming effects over lags along with evidence of persistence based on the proportion of alternative structures produced or comprehended. However, as with the lack of consensus about the locus of the short-lived lexical boost, the source of the decaying component of abstract syntactic priming is not clear — it could result from either transience of the residual activation of the structural representation (Pickering & Branigan, 1998), or dissipating explicit STM of the sentence structure (as was argued in Bernolet et al., 2016), or both (Branigan & McLean, 2016).

It is, however, also possible to accommodate the lexical boost in a single-mechanism account of syntactic priming, where priming effects reflect adaptation based on prediction error (Jaeger & Snider, 2013). This adaptation account claims that priming effects reflect
an overall goal for efficient communication, in part by accurately predicting the structure of future sentences and using sentences that will be easy for one’s communication partner to understand. Thus, priming reflects speakers aligning their production preferences to their expectations about their interlocutors. By this account, changes in syntactic production (i.e., syntactic priming) reflect adaptation in light of prediction errors, and so prime sentences with higher syntactic surprisal are associated with larger prediction errors, and thus greater adaptation and greater priming effects. In many ways, this account is similar to error-based learning accounts (Chang et al., 2006); it is similarly independent of explicit memory and so similarly accounts for many findings including the inverse frequency effect and priming from incomplete sentences (Ivanova, Branigan, McLean, Costa, & Pickering, 2017; Slevc & Ferreira, 2013). Importantly, this adaptation account can also explain the lexical boost, given that a prime sentence is likely a better predictor of the future structure to be used with that same verb than that to be used with a different verb. The relatively short time course of this lexical boost can be accommodated by assuming that the informativity of lexical cues decay faster than the informativity of structural cues, thus lexically based expectations have a shorter-lived influence than structurally-based ones. This follows from the idea that topics “cluster” in natural language, and so lexical recurrence typically happens over relatively short timescales (e.g., Qian & Jaeger, 2012).

In sum, there seems to be a consensus that long-lived abstract syntactic priming effects reflect some type of implicit learning process, though explicit memory could also have a role in supporting this priming in the short term. However, the underlying mechanism leading to the short-lived lexical boost is less clear. Most theories suggest the
lexical boost reflects transient activation in STM (Chang et al., 2006; Ferreira & Bock, 2006; Hartsuiker et al., 2008; Reitter et al., 2011), but other accounts suggest that the lexical boost results from residual activation of linguistic representations (Pickering & Branigan, 1998), from both traces in STM and residual activation (Branigan & McLean, 2016), or from the same implicit adaptation mechanisms that lead to long-term abstract syntactic priming effects (Jaeger & Snider, 2013). The aim of the present experiment was to directly test whether the lexical boost effect in syntactic priming derives from explicit STM, or if it, like long-term abstract syntactic priming effects, reflects some type of automatic/implicit effect such as residual activation or expectation adaptation. To this end, the current study examined syntactic priming in brain damaged patients with verbal STM deficits. I examined both the abstract priming effect and the lexical boost effect, primarily focusing on whether the degree of deficit in STM would account for variations in the lexical boost effect, though also examining the relation of STM deficits to abstract syntactic priming.

If explicit memory is indeed the locus of short-lived lexical boost (e.g., Chang et al., 2006; Reitter et al., 2011), then there should be a memory mechanism that supports the short-term retention of the sentence structure and the verb in the prime sentence, so that in an immediately following sentence, speakers can use the verb as a cue to retrieve structural information from the memory. Specifically, speakers should have a STM store to maintain at least the syntactic information of the sentence structure, and either the phonological or semantic information of the verb. However, to do this in a syntactic priming experiment, speakers would have to be able to remember not only the verb (e.g., *chase*), but also all arguments associated with the verb (e.g., *lion, hiker*) to ensure
successful retrieval of the verb and the associated structural information at a later time. This is because, at least in the design of the current study, there is no reason to assume that participants would form a strategy to selectively remember the verb and the specific sentence structure type (e.g., “active”, “passive”).

Martin and colleagues (Allen, Martin, & Martin, 2012; Martin & He, 2004) and others (e.g., Barde, Schwartz, Chrysikou, & Thompson-Schill, 2010) have shown that patients may be selectively impaired in maintaining lexical-semantic or phonological information and thus the ability to retain both types of information were assessed. However, patients included in this study all showed high levels of single word comprehension and production. If the lexical boost relies on explicit short-term retention of the sentence form and the verb, the degree of patients’ STM deficit should be related to the size of the lexical boost effect. If, on the other hand, the lexical boost effect reflects the same (non-STM-mediated) adaptation processes as the abstract syntactic priming effects (Jaeger & Snider, 2013), then patients’ lexical boost effects should be similar to controls’ despite the patients’ STM deficits. STM measurements were also collected from control speakers to also explore any possible relationship between STM capacities and lexical boost effects in control speakers. However, data from control speakers were not predicted to be critical in deciding if STM subserves the lexical boost. This is because even the control speaker with the lowest STM capacities had STM spans of around four words in several list recall tasks (shown in Table 1.1), which were larger than most patients and also sufficient to maintain the information of the prime sentence. Therefore, if no correlation between STM capacities and lexical boost effects could be found in controls, one might argue that this cannot be taken as evidence against the STM account
of lexical boost, and may just show a possibility that control speakers had no difficulty in retrieving verb and structural information of the prime sentence to support target sentence production.

More specifically, most major theories of abstract syntactic priming, including the residual activation account, the implicit learning account, and the adaptation account, would predict that patients with STM deficits should show similar abstract priming effects as control speakers (so long as these patients have relatively preserved representations of sentence structures and no impairment in implicit learning). Indeed, prior studies with aphasic patients, even for those having varying degrees of syntactic disruption in sentence production, have found evidence for syntactic priming in that their production of relatively complex structures (e.g., passives) increased after their processing of corresponding primes (Hartsuiker & Kolk, 1998; Saffran & Martin, 1997). Similar results were also reported among bilingual aphasic patients (Verreyt et al., 2013) and children with Specific Language Impairment (Garraffa, Coco, & Branigan, 2015). Thus, these theories would predict that our patients would show abstract syntactic priming effects. However, if syntactic priming is subserved by dual processes of both long-term implicit learning and short term explicit memory (Bernolet et al., 2016), then patients in the current study should show a relationship between their STM capacities and the syntactic priming effects. In terms of lexical boost effects, dual-locus accounts of priming where the lexical boost reflects transient activation in STM predicts that patients with STM deficits should show smaller or non-existent lexical boost effects, whereas the residual activation account and the single-locus adaptation-based account predict that patients and controls should show similar lexical boost effects.
Experiment 1.1 Syntactic priming task

Methods

Similar to many syntactic priming studies, the current experiment used a picture description task in which patients repeated primes and described target pictures. Experimental sentences involved alternations of transitive structure (active vs. passive).

Participants

Twelve aphasic patients with varying degrees of verbal STM impairment after stroke and eleven age-matched healthy control speakers from the local community participated in the study. Patients’ mean age was 63 (range: 47-86) and they had a mean of 15 years of education. Control speakers’ mean age was 73 (range: 61-87), and they had a mean of 16 years of education. In order to increase the number of trials, six patients and five control speakers were tested twice on the same tasks with an average interval of 21 months for patients and 15 months for control speakers. Six patients and six control speakers did the tasks only once either because they were not available for a second round of testing, or because they had been tested shortly before this manuscript was prepared. Appendix A shows individual patients’ stroke information. Table 1.1 shows the background information for patients and controls on various STM and language processing tasks. A description of the STM tasks is provided in the Materials and Procedure section. Although they all had deficits in semantic STM (category probe span) and on at least one of the phonological STM tests (rhyme probe, digit matching and digit span), their degrees of impairment varied considerably, making it possible to explore the relationship between individual differences in STM and lexical boost effects. Generally patients were relatively preserved in noun processing, with most of them within the
control range in the Philadelphia Naming Test (PNT; Roach, Schwartz, Martin, Grewal, & Brecher, 1996) and the picture-word matching task (Martin, Lesch, & Bartha, 1999). Patients were slightly more impaired in verb processing, as shown in the verb picture naming test (Berndt, Mitchum, Haendiges, & Sandson, 1997). On another verb processing index in the Quantitative Production Analysis (QPA), which is based on a story-retelling task (Rochon, Saffran, Berndt, & Schwartz, 2000; Saffran, Berndt, & Schwartz, 1989), patients were generally in normal range in the proportion of verbs to nouns (V/N+V). Therefore, patients’ verb processing impairments in general were mild. According to the QPA, patients had generally preserved morphological aspects of production but varied considerably on structural aspects. Relative to controls several patients showed a low proportion of well-formed sentences, reduced median length of utterance and a reduced sentence elaboration index, which reflects the number of content words in the head noun and matrix verb phrases.
Table 1.1 STM span, word processing and sentence production data of patients and healthy control speakers.

(Patients ordered by category probe spans.)

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>LC</th>
<th>RI</th>
<th>PP</th>
<th>GP</th>
<th>RR</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>67</td>
<td>47</td>
<td>56</td>
<td>64</td>
<td>57</td>
<td>50</td>
<td>66</td>
<td>66</td>
<td>86</td>
<td>67</td>
<td>56</td>
<td>72</td>
<td>73</td>
<td>61-87</td>
</tr>
<tr>
<td><strong>Years of education</strong></td>
<td>16</td>
<td>14.5</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>13</td>
<td>13</td>
<td>12</td>
<td>20</td>
<td>16</td>
<td>14</td>
<td>16</td>
<td>12-19</td>
</tr>
<tr>
<td><strong>STM measures (span)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>category probe</td>
<td>0.71</td>
<td>1</td>
<td>1.33</td>
<td>1.83</td>
<td>2</td>
<td>2.37</td>
<td>2.38</td>
<td>2.71</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
<td>4.14</td>
<td>6.2</td>
<td>3.50-7.22</td>
</tr>
<tr>
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<td>4.8</td>
<td>5</td>
<td>2.56</td>
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<td>1.67</td>
<td>4</td>
<td>4</td>
<td>1.8</td>
<td>6.79</td>
<td>3.66-10</td>
</tr>
<tr>
<td>digit matching</td>
<td>2</td>
<td>4.5</td>
<td>4.72</td>
<td>5.8</td>
<td>6</td>
<td>4.72</td>
<td>3.56</td>
<td>3</td>
<td>4</td>
<td>3.68</td>
<td>5.35</td>
<td>6</td>
<td>6</td>
<td>*</td>
</tr>
<tr>
<td>digit span</td>
<td>3</td>
<td>3.5</td>
<td>3.5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>3.5</td>
<td>3.5</td>
<td>4.5</td>
<td>4.55-9</td>
<td></td>
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<tr>
<td><strong>Lexical processing (% correct)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PNT</td>
<td>0.79</td>
<td>0.90</td>
<td>0.94</td>
<td>0.80</td>
<td>0.86</td>
<td>0.90</td>
<td>0.97</td>
<td>0.89</td>
<td>0.93</td>
<td>0.98</td>
<td>0.94</td>
<td>0.90</td>
<td>0.97</td>
<td>0.82-1</td>
</tr>
<tr>
<td>Pic-word matching N.</td>
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<td>0.94</td>
<td>0.93</td>
<td>0.97</td>
<td>0.95</td>
<td>0.98</td>
<td>0.97</td>
<td>0.98</td>
<td>0.95</td>
<td>1.00</td>
<td>0.95</td>
<td>0.99</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>BERNT VERB</td>
<td>0.80</td>
<td>0.73</td>
<td>0.80</td>
<td>0.60</td>
<td>0.73</td>
<td>1.00</td>
<td>0.83</td>
<td>0.87</td>
<td>0.80</td>
<td>0.97</td>
<td>0.83</td>
<td>0.83</td>
<td>0.98</td>
<td>0.97-1</td>
</tr>
<tr>
<td><strong>QPA indexes</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td><strong>Lexical content</strong></td>
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<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td># Words per Minute</td>
<td>53</td>
<td>67</td>
<td>88</td>
<td>81</td>
<td>138</td>
<td>80</td>
<td>68</td>
<td>58</td>
<td>67</td>
<td>145</td>
<td>70</td>
<td>69</td>
<td>161</td>
<td>107-232</td>
</tr>
<tr>
<td>Prop. Closed Class Words</td>
<td>0.50</td>
<td>0.58</td>
<td>0.52</td>
<td>0.59</td>
<td>0.55</td>
<td>0.62</td>
<td>0.53</td>
<td>0.54</td>
<td>0.58</td>
<td>0.63</td>
<td>0.50</td>
<td>0.54</td>
<td>0.54</td>
<td>0.47-0.61</td>
</tr>
<tr>
<td>DET Index</td>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.91</td>
<td>1.00</td>
<td>0.97</td>
<td>0.75</td>
<td>0.94</td>
<td>1.00</td>
<td>0.86</td>
<td>0.96</td>
<td>0.99</td>
<td>0.94-1</td>
</tr>
<tr>
<td>Prop. Pronouns</td>
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<td>0.60</td>
<td>0.39</td>
<td>0.59</td>
<td>0.46</td>
<td>0.58</td>
<td>0.31</td>
<td>0.41</td>
<td>0.47</td>
<td>0.52</td>
<td>0.57</td>
<td>0.03</td>
<td>0.41</td>
<td>0.29-0.55</td>
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<tr>
<td>Prop. Verbs</td>
<td>0.43</td>
<td>0.59</td>
<td>0.45</td>
<td>0.63</td>
<td>0.55</td>
<td>0.55</td>
<td>0.44</td>
<td>0.50</td>
<td>0.48</td>
<td>0.59</td>
<td>0.57</td>
<td>0.33</td>
<td>0.48</td>
<td>0.35-0.63</td>
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<tr>
<td>Inflection Index</td>
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<td>0.87</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.83</td>
<td>1.00</td>
<td>1.00</td>
<td>0.92</td>
<td>0.71</td>
<td>1.00</td>
<td>0.92</td>
<td>0.53-1</td>
<td></td>
</tr>
<tr>
<td>Aux Complexity Index</td>
<td>1.38</td>
<td>1.27</td>
<td>1.06</td>
<td>1.81</td>
<td>1.32</td>
<td>1.07</td>
<td>1.23</td>
<td>2.29</td>
<td>1.11</td>
<td>1.17</td>
<td>1.00</td>
<td>1.71</td>
<td>0.83-1.71</td>
<td></td>
</tr>
<tr>
<td><strong>Structural analysis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prop. Words in Ss</td>
<td>0.96</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
<td>0.96</td>
<td>0.98</td>
<td>0.78</td>
<td>0.97</td>
<td>0.88</td>
<td>0.95</td>
<td>0.95</td>
<td>1.00</td>
<td>0.98</td>
<td>0.84-1</td>
</tr>
<tr>
<td>Prop. Well-Formed Ss</td>
<td>0.70</td>
<td>0.79</td>
<td>0.81</td>
<td>0.87</td>
<td>0.95</td>
<td>0.78</td>
<td>0.73</td>
<td>0.50</td>
<td>0.79</td>
<td>0.79</td>
<td>0.67</td>
<td>0.71</td>
<td>0.93</td>
<td>0.75-1</td>
</tr>
<tr>
<td>Embedding Index</td>
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<td>0.23</td>
<td>0.38</td>
<td>0.20</td>
<td>0.23</td>
<td>0.17</td>
<td>0.00</td>
<td>0.33</td>
<td>0.16</td>
<td>0.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.29</td>
<td>0-0.5</td>
</tr>
<tr>
<td>Median utterance length</td>
<td>9.86</td>
<td>7.06</td>
<td>8.50</td>
<td>6.70</td>
<td>5.00</td>
<td>7.37</td>
<td>5.00</td>
<td>9.00</td>
<td>6.00</td>
<td>8.91</td>
<td>5.05</td>
<td>5.57</td>
<td>8.17</td>
<td>6.5-10.5</td>
</tr>
<tr>
<td>S Elaboration Index</td>
<td>2.95</td>
<td>2.57</td>
<td>3.69</td>
<td>1.82</td>
<td>2.10</td>
<td>2.09</td>
<td>1.39</td>
<td>1.72</td>
<td>2.06</td>
<td>1.57</td>
<td>1.90</td>
<td>1.36</td>
<td>3.06</td>
<td>2.14-4.06</td>
</tr>
</tbody>
</table>

* The longest list length that can be achieved in the digit matching task is 6, and all control speakers performed at a ceiling level in the task.
Materials and procedure

Syntactic priming task

Four lists of 64 trials were constructed. Each list contained 32 experimental trials that paired transitive prime sentences with transitive-eliciting pictures, as well as 32 filler trials of which 16 were dative prime/target pairs and 16 were prime/target trials with varying syntactic properties (e.g. the cafe was out of tea). Unlike many other syntactic priming studies, the current experiment did not treat dative trials as experimental items because pilot studies showed that many of our patient participants only produced prepositional dative sentences in response to dative target pictures and had difficulty processing double object sentences. I will discuss this in the results and discussion section. The four lists paired the same set of experimental target pictures with prime sentences in each of the four different conditions – that is, the counterbalanced crossing of the prime’s syntactic structure (active vs. passive) with verb repetition (same vs. different prime/target verb). Thus, in each list, half of the transitive primes were actives and the other half were passives, and half of the dative primes were double object datives (DO) and the other half were prepositional datives (PD). Within each structure condition, half of the primes had the same verb as the targets. Among the transitive target pictures in each list, all theme nouns were humans. Nine of the pictures had a human agent (e.g., the ballerina kissed the artist), nine had an animal agent (e.g., the dog rescued the skier), and another 14 had an inanimate agent (e.g., the sprinkler sprayed the farmer). The purpose of using pictures with non-human agents was to boost passive responses (see Bock, 1986; Harris, 1978). See Appendix B for a list of sentence materials used in the current experiment. Each participant completed all
four lists, with at least a four-day interval between two lists. In order to obtain more power to detect effects, about half of the participants performed the same task again about one year later.

The priming task was presented by Psycscope X B51 (Bonatti, 2010; Cohen, MacWhinney, Flatt, & Provost, 1993). Before the experiment, participants previewed pictures of individual objects and human characters appearing in the target pictures and did five practice trials (including three intransitive, one transitive and one dative target sentences). On each trial, participants first heard a prime sentence, and were instructed to repeat the sentence (e.g. the referee was punched by the player). After participants tried to repeat the prime, they saw the prime sentence on the screen and had to read it aloud whether or not they had repeated it correctly. Patients generally had no difficulty in correctly reading the sentence aloud. In the rare circumstances where a reading error was made, the experimenter corrected the patient until the patient could read the sentence correctly. Following prime processing, they saw the target picture (see Figure 1.1 for an example) with the main verb in its past tense form (e.g. chased) written at the bottom of the screen and played auditorily through the computer sound system. Participants were asked to describe the picture in a sentence using the given verb (e.g. the hiker was chased by the bear). The verbs were provided in inflected form to reduce any potential difficulty with verb inflection in patients, although most of them scored high on the inflection index of QPA shown in Table 1.1. All verbs had the same inflected form for the past tense and the past participle, so that they can be used in both active and passive structures. Patients took about 40 minutes on average to complete a list, compared to 25 minutes for controls.
**STM measures**

To assess patients STM abilities, the current experiment used both standard word list recall and recognition paradigms to assess sentence memory. The list recall tasks tapped both semantic and phonological aspects of STM. The category probe task was used to assess semantic STM and three other tasks were used to assess phonological STM, namely the rhyme probe, digit matching span and digit span tasks (Allen et al., 2012; Martin, Shelton, & Yaffee, 1994). In the category probe task, participants judged whether a probe word was in the same semantic category as any preceding list word. For example, in a two-word list, participants might have heard “cherry” and “donkey”, and then the probe word “lemon”. The correct response would be “yes” because “lemon” and “cherry” both belonged to the fruit category. In the rhyme probe task, they judged whether a probe word rhymed with any preceding list word. For example, they might have heard “well” and “less” and then the probe word of “mess”, and should respond “yes” because “mess” rhymes with “less”. In the digit matching span task, they judged whether two
digit lists were the same or not where the nonmatching lists differed in the order of two adjacent
digits. For all these three tasks, testing started at list length 2 and list length was increased until
performance dropped below 75% correct at a given length. There were 20-36 trials at each list
length. Spans were estimated as the list length at which they would score 75% correct through
linear interpolation between the two lengths spanning 75% correct. The digit span task had two
trials at each list length and participants needed to repeat the digits in the same order they were
presented. Their digit span was determined as the list length at which they repeated at least one
of the trials correctly. The longest list that could be achieved was 7 for the category probe task,
10 for the rhyme probe task, 6 for the digit matching span task, and 9 for the digit span task. Data
was collected on category probe spans, rhyme probe spans, digit matching spans and digit spans
from all patients and 8 control speakers. The other 3 control speakers were tested on the syntactic
priming task before the decision was made to collect STM measures from control speakers, and
were not available later for additional testing.

To assess sentence memory, I used participants’ accuracies in repeating the prime
sentences and their accuracy in specifically repeating the verbs in the prime sentences. These
allowed us to assess memory for sentence structure and the identity of the verb. One caveat with
these measures is that deficits in language output might affect their abilities to repeat sentences.
Thus, a novel paradigm was designed to assess participants’ STM for sentences, which involved
deciding whether or not a probe sentence matched a preceding sentence.

*Sentence STM task.* This task examined participants’ abilities to maintain sentence
information by using a sentence probe task in which participants judged if a probe sentence was
exactly the same as a sentence that they just processed. The task manipulated both structural and
lexical factors to specifically test participants’ STM capacity for different aspects of the sentence,
and also to discourage participants from focusing on only one aspect of the sentences. Table 1.2 shows example probes in different conditions for one of the target sentences (“The enemy followed the spy”). In the same structure/ different verb condition, the probe was different from the target sentence only in the verb; in the same structure/ different noun condition, half of the probes had a different agent noun, and the other half had a different theme noun. These two conditions tested participants’ STM for lexical items in a sentence context. Another condition, the different structure/ same meaning condition, tested participants’ abilities to maintain structural information. Probes in the different structure/ different meaning condition reversed the role of the agent and the theme, and also changed the structure. This condition was designed to ensure that participants effectively processed and maintained the syntax during the task. Potentially, for a target sentence such as “The enemy followed the spy,” participants could have performed well on other conditions just by remembering three content words and their order in the sentence (e.g., enemy, follow, spy) without further processing of the syntax. But this memory tactic would not be able to help them judge a non-matched probe sentence like “The enemy was followed by the spy,” which requires syntactic processing to differentiate it from the target sentence. I focused on performance in the different-verb condition and in the different structure/ same meaning condition, because they were especially relevant to examine the possible role of STM in the lexical boost of syntactic priming because these two conditions specifically examined participants’ explicit STM of the verb and the structure in the prime sentence (Ferreira & Bock, 2006; Chang, Dell & Bock, 2006). In addition to more specific comparisons, I also collapsed the five different conditions and used participants’ performance on all transitive trials as an overall measurement of their sentence STM capacities.
Table 1.2 Example probes in different conditions for the target sentence: *The enemy followed the spy* in the sentence STM task

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example</th>
<th># of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same structure/ different verb</td>
<td><em>The enemy</em> captured <em>the spy.</em></td>
<td>8</td>
</tr>
<tr>
<td>Same structure/ different noun</td>
<td><em>The soldier</em> followed <em>the spy</em>. Or, <em>The enemy followed the soldier.</em></td>
<td>8</td>
</tr>
<tr>
<td>Different structure/ same meaning</td>
<td><em>The spy was followed by the enemy.</em></td>
<td>8</td>
</tr>
<tr>
<td>Different structure/ different meaning</td>
<td><em>The enemy was followed by the spy.</em></td>
<td>8</td>
</tr>
<tr>
<td>Matched</td>
<td><em>The enemy followed the spy.</em></td>
<td>16</td>
</tr>
</tbody>
</table>

The 32 target sentences in the four non-matching conditions were identical to the transitive prime sentences in the syntactic priming task. The 16 target sentences in the matching condition were taken from the target sentences in the same syntactic priming task. There were also 40 filler trials, 20 with dative sentences and 20 with intransitive sentences, also adapted from the syntactic priming task. Across all 88 trials, half of the trials were matching and half non-matching. The task was administered at least a month after the completion of the syntactic priming task.

Each trial began with a series of dashes shown on the computer screen. The to-be-remembered sentence was played over speakers and participants were asked to repeat it. Then the written version of the sentence appeared on the screen and participants read it aloud. The sentence was then replaced with two pictures unrelated to the sentence, which the participant was asked to name aloud. Following naming, the sentence was replaced by a series of asterisks for 3
seconds. Then the probe sentence was presented visually and the participant indicated whether it was identical to the target sentence.

Picture naming was introduced between presentation of the target sentence and the probe sentence because, in the syntactic priming experiment, subjects saw a picture that they had to encode after repeating the priming sentence. If syntactic priming depended on participants’ explicit memory for the prime, this memory had to persist during their encoding of the picture and retrieval of the names for the entities in it. Thus, the picture naming step was designed to approximate this process without involving access to a sentence structure. This manipulation disrupted the use of verbatim rehearsal in remembering the target sentence. Note that in the syntactic priming tasks in the current study, participants were never asked or motivated to remember the prime sentences. The target sentence was presented in sentence case whereas the probe sentence was presented in all caps in a slightly larger font size to prevent the participant from making judgments based on visual similarity between the target sentence and the probe sentence. Nine of the twelve patients and 6 control speakers were available for the sentence STM task. Patients took about 45 minutes to complete the task while control speakers generally finished within 30 minutes.

**Scoring and data analysis**

For the sentence STM task, participants’ overall accuracy rates as well as their $d'$ scores (Macmillan & Creelman, 2004) on the transitive trials were calculated. These scores provide an unbiased measurement of participants’ ability to discriminate between matched and unmatched probes. The hit rate was defined as the percentage correct on the matched trials and the false alarm rate as the percentage incorrect on the unmatched trials (i.e., the proportion of “yes”
responses on unmatched trials). Extreme rates were adjusted by replacing 0% with 0.5/n and 100% with (n−0.5)/n, where n is the number of trials used to compute hit rates and false alarm rates. (Macmillan & Kaplan, 1985). Similarly, participants’ $d'$ scores in the same structure/ different verb condition and in the same meaning/ different structure condition were also calculated. These provide an assessment of participants’ ability to maintain information about the verb and the structure, and are thus highly relevant for exploring the role of STM in lexical boost.

The following scheme was used to calculate participants’ accuracies in repeating the prime sentences and the verbs in the primes. As long as the sentence produced was grammatical, any sentence that differed from the prime sentence in grammatical morphemes which were unrelated to the active-passive difference (e.g., differences in present vs. past tense, definite vs. indefinite article, singular vs. plural noun) were scored as correct. For example, repeating the fireman rescued the cat as a fireman was rescuing the cats was considered as correct. Any other change of content words or the sentence structure was scored as a sentence repetition error. In order to further explore whether explicit memory for verbs in prime sentences accounts for the lexical boost or syntactic priming effects, I also calculated patients’ proportion of verb repetition errors, e.g., repeating the verb incorrectly: the fireman saved the cat, or failing to repeat the verb: the fireman... the cat. One might expect that verb errors would be likely to reduce syntactic priming if such priming depends on explicit memory for the verb and associated sentence structure.

Participants’ responses to the target picture were coded manually. A transitive target sentence was coded as active, passive, or other. A dative target sentence was coded as DO, PD
or other. A strict coding scheme was used in line with most past research\(^3\) (e.g. Bock, 1986; Pickering & Branigan, 1998). The abstract syntactic priming effect was defined as the difference in the proportion of active responses out of all active/passive responses between the active prime condition and the passive prime condition. The lexical boost effect was calculated by subtracting the abstract priming effect in the different verb condition from the priming effect in the same verb condition.

**Results and discussion**

In order to reduce the data and obtain a more reliable measure of the underlying construct, I combined the three phonological STM measures (rhyme probe, digit span, and digit matching span) into one composite score by calculating the average of \(z\)-scores for each measure (Pettigrew & Martin, 2016), with higher scores indicating better STM capacities (see Table 1.3). Because control speakers performed at a ceiling level on the digit matching task, the phonological STM composite scores for them only used rhyme probe and digit span. Control speakers also had near-ceiling performance on all sentence STM measures and thus their scores were not used for further correlation analysis. Patients showed considerable variation on the sentence STM measures, as shown in Table 1.3. All patients scored below the range of controls on overall accuracy in sentence repetition and all but one scored below the control range on overall \(d'\) for the sentence memory test. Patients’ accuracies in repeating the prime sentence and the verb in the prime in the syntactic priming task correlated significantly with both category probe spans and the phonological STM composite scores, both \(rs > .65, ps < .03\), indicating a

---

\(^3\) The only patient study of syntactic priming that did not use a strict coding scheme was Saffran and Martin (1997), which accepted ill-formed passives like *the boy is stinging to the bee*. This might partially account for a large syntactic priming effect of 23% in transitive trials among aphasic patients in that study.
strong involvement of both semantic and phonological STM in repeating prime sentences. A multiple regression analysis revealed that semantic and phonological STM contributed independently to the repetition of the prime sentences and together accounted for 76% of the variance. By comparison, patients’ overall $d'$ scores in the sentence STM task had a moderate (though not significant) correlation with the phonological composite, $r(8) = .47$, $p = .18$, and semantic and phonological STM measures together only accounted for 26% of variance in the overall $d'$ scores in the sentence STM task. These findings indicate that other factors contributed more towards performance on this sentence STM task, with perhaps memory for sentence structure or memory for the overall meaning of the sentence playing a larger role.
Table 1.3 Participants’ STM capacities measured by different tasks

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>LC</th>
<th>RI</th>
<th>PP</th>
<th>GP</th>
<th>RR</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Word list STM scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category probe</td>
<td>0.71</td>
<td>1</td>
<td>1.33</td>
<td>1.83</td>
<td>2</td>
<td>2.37</td>
<td>2.38</td>
<td>2.71</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
<td>4.14</td>
<td>6.2</td>
<td>3.50-7.22</td>
</tr>
<tr>
<td>Phono. composite</td>
<td>-1.45</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.75</td>
<td>1.48</td>
<td>0.37</td>
<td>-0.73</td>
<td>-0.81</td>
<td>-0.62</td>
<td>0.06</td>
<td>0.50</td>
<td>0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Accuracy in repeating transitive primes</strong></td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Sentence</td>
<td>0.06</td>
<td>0.13</td>
<td>0.25</td>
<td>0.88</td>
<td>0.98</td>
<td>0.78</td>
<td>0.13</td>
<td>0.75</td>
<td>0.38</td>
<td>0.87</td>
<td>0.91</td>
<td>0.92</td>
<td>0.99</td>
<td>0.98-1</td>
</tr>
<tr>
<td>Verb</td>
<td>0.25</td>
<td>0.34</td>
<td>0.54</td>
<td>0.95</td>
<td>1.00</td>
<td>0.86</td>
<td>0.30</td>
<td>0.90</td>
<td>0.72</td>
<td>0.95</td>
<td>1.00</td>
<td>1.00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Accuracy in sentence STM task</strong></td>
<td></td>
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<tr>
<td>Overall accuracy</td>
<td>0.68</td>
<td>0.81</td>
<td>0.88</td>
<td>0.85</td>
<td>0.81</td>
<td>0.98</td>
<td>0.90</td>
<td>0.90</td>
<td>0.58</td>
<td>0.98</td>
<td>0.96-1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Different verb</td>
<td>0.33</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
<td>1.00</td>
<td>0.88</td>
<td>0.25</td>
<td>0.99</td>
<td>0.88-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Different structure</td>
<td>0.50</td>
<td>0.88</td>
<td>0.75</td>
<td>1.00</td>
<td>0.88</td>
<td>1.00</td>
<td>0.88</td>
<td>1.00</td>
<td>0.50</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>d’ scores in sentence STM task</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Overall</td>
<td>1.21</td>
<td>2.21</td>
<td>3.20</td>
<td>3.09</td>
<td>2.89</td>
<td>4.17</td>
<td>2.68</td>
<td>2.47</td>
<td>1.99</td>
<td>4.18</td>
<td>3.40-4.62</td>
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</tr>
<tr>
<td>Different verb</td>
<td>0.64</td>
<td>3.85</td>
<td>4.62</td>
<td>4.62</td>
<td>2.99</td>
<td>4.62</td>
<td>3.85</td>
<td>2.30</td>
<td>1.64</td>
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<tr>
<td>Different structure</td>
<td>1.07</td>
<td>2.68</td>
<td>2.99</td>
<td>4.62</td>
<td>3.46</td>
<td>4.62</td>
<td>2.68</td>
<td>3.46</td>
<td>2.31</td>
<td></td>
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</tr>
</tbody>
</table>
Table 1.4 shows the proportion of response types from each patient and the control group with transitive target sentences. Patients produced comparable proportions of passives as healthy speakers, showing a preserved ability to formulate transitive sentence structures (cf. Hartsuiker & Kolk, 1998; Saffran & Martin, 1997). Note that patients did not need a passive prime sentence to be able to produce the passive structure; even after active prime sentences, 23% of responses were in the passive form. However, for many of the patients, this paradigm elicited very limited production of the DO construction, with 4 of the 12 patients producing 1% or fewer DO constructions overall, making the analysis of priming effects with dative sentences difficult to interpret. Therefore, further data analysis focused on transitive trials, where the proportions of passives for the four patients producing the least were 9%, 10%, 21% and 25%.
Table 1.4 Percent response types in target sentences in Exp. 1.1

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>LC</th>
<th>RI</th>
<th>PP</th>
<th>GP</th>
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<th>Control Mean</th>
<th>Control Range</th>
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</thead>
<tbody>
<tr>
<td>Transitives</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>0.56</td>
<td>0.69</td>
<td>0.80</td>
<td>0.62</td>
<td>0.55</td>
<td>0.58</td>
<td>0.49</td>
<td>0.60</td>
<td>0.50</td>
<td>0.34</td>
<td>0.76</td>
<td>0.68</td>
<td>0.56</td>
<td>0.38-0.79</td>
</tr>
<tr>
<td>Passive</td>
<td>0.35</td>
<td>0.21</td>
<td>0.10</td>
<td>0.30</td>
<td>0.28</td>
<td>0.35</td>
<td>0.35</td>
<td>0.33</td>
<td>0.28</td>
<td>0.52</td>
<td>0.09</td>
<td>0.25</td>
<td>0.37</td>
<td>0.16-0.59</td>
</tr>
<tr>
<td>Other</td>
<td>0.09</td>
<td>0.10</td>
<td>0.10</td>
<td>0.09</td>
<td>0.17</td>
<td>0.07</td>
<td>0.16</td>
<td>0.07</td>
<td>0.21</td>
<td>0.13</td>
<td>0.15</td>
<td>0.07</td>
<td>0.07</td>
<td>0.01-0.14</td>
</tr>
<tr>
<td>Datives</td>
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</tr>
<tr>
<td>PD</td>
<td>0.89</td>
<td>0.77</td>
<td>0.91</td>
<td>0.81</td>
<td>0.46</td>
<td>0.69</td>
<td>0.92</td>
<td>0.93</td>
<td>0.90</td>
<td>0.77</td>
<td>0.70</td>
<td>0.27</td>
<td>0.83</td>
<td>0.59-0.98</td>
</tr>
<tr>
<td>DO</td>
<td>0.05</td>
<td>0.06</td>
<td>0.01</td>
<td>0.05</td>
<td>0.39</td>
<td>0.31</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.19</td>
<td>0.50</td>
<td>0.13</td>
<td>0.02-0.38</td>
</tr>
<tr>
<td>Other</td>
<td>0.06</td>
<td>0.17</td>
<td>0.08</td>
<td>0.14</td>
<td>0.16</td>
<td>0.00</td>
<td>0.07</td>
<td>0.07</td>
<td>0.10</td>
<td>0.20</td>
<td>0.11</td>
<td>0.23</td>
<td>0.03</td>
<td>0-0.16</td>
</tr>
</tbody>
</table>

Table 1.5 Percent priming effects in transitive trials in Exp. 1.1

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>LC</th>
<th>RI</th>
<th>PP</th>
<th>GP</th>
<th>RR</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priming effects</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.44</td>
<td>0.08</td>
<td>0.05</td>
<td>0.06</td>
<td>-0.04</td>
<td>0.28</td>
<td>0.09</td>
<td>0.13</td>
<td>0.10</td>
<td>0.32</td>
<td>0.14</td>
<td>0.01</td>
<td>0.19</td>
<td>-0.02-0.61</td>
</tr>
<tr>
<td>Same verb</td>
<td>0.50</td>
<td>0.10</td>
<td>0.09</td>
<td>0.15</td>
<td>-0.03</td>
<td>0.40</td>
<td>0.22</td>
<td>0.15</td>
<td>0.20</td>
<td>0.40</td>
<td>0.17</td>
<td>0.02</td>
<td>0.26</td>
<td>0.01-0.72</td>
</tr>
<tr>
<td>Different verb</td>
<td>0.38</td>
<td>0.06</td>
<td>0.02</td>
<td>-0.04</td>
<td>-0.05</td>
<td>0.16</td>
<td>-0.05</td>
<td>0.10</td>
<td>-0.01</td>
<td>0.23</td>
<td>0.12</td>
<td>0.01</td>
<td>0.13</td>
<td>-0.05-0.50</td>
</tr>
<tr>
<td>Lexical boost</td>
<td>0.12</td>
<td>0.04</td>
<td>0.06</td>
<td>0.19</td>
<td>0.02</td>
<td>0.24</td>
<td>0.27</td>
<td>0.05</td>
<td>0.21</td>
<td>0.17</td>
<td>0.05</td>
<td>0.01</td>
<td>0.13</td>
<td>0-0.36</td>
</tr>
</tbody>
</table>
Table 1.5 reports participants’ syntactic priming effects (both with and without prime/target verb overlap) and their lexical boost effects on critical (transitive) trials. For control speakers, analysis using linear mixed-effects (LME) logistic regression models with the maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013) showed a significant priming effect of 19% with transitive trials ($Z = 3.83$, $p < .001$) and a lexical boost effect (i.e., an interaction between structure and verb overlap) of 13%, $Z = 3.76$, $p < .001$. In other words, when the verb differed from the prime to the target sentence, the proportion of actives increased by 13%, from 53% following passive primes to 67% following active primes; when the verb was the same between the prime and the target sentences, the proportion of actives increased by 26%, from 48% after passive primes to 75% after active primes. The 13% priming effect in the different verb condition and the 13% lexical boost effect in control speakers were very similar to a meta-analysis based on 73 syntactic priming studies, showing a 13% priming effect and a 14% lexical boost effect on average (Mahowald, James, Futrell, & Gibson, 2016). In the different verb condition, eight of the twelve patients showed a positive syntactic priming effect and nine of eleven controls showed a positive priming effect (see Figure 1.2a). Following a method developed to compare an individual score with a small normative sample (Crawford, Garthwaite, & Porter, 2010), no individual patient showed an abstract priming effect that was significantly different from control effects (all $p$s > .13). Although the mean abstract syntactic priming effect

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4 Similar results were obtained in ANOVAs. I calculated proportions of active responses out of all active and passive responses in four conditions (active/passive prime * same/different verb), and took the arcsine transformed data of these proportions as the dependent variable, treating prime construction and verb sameness as the within subject and within item factors. There was a significant main effect of prime construction, $F_1 (1, 10) = 15.47, MSE = .043, p = .003; F_2 (1, 31) = 96.61, MSE = .036, p < .001$. The lexical boost effect was also significant, $F_1 (1, 10) = 15.87, MSE = .006, p = .003; F_2 (1, 31) = 22.27, MSE = .017, p < .001$. 

was slightly lower for patients (8%) than for control speakers (13%), the difference was not significant, $t(21) = .85, p = .40$, given the high variability in priming effects for both groups.

For the same verb condition, all of the controls and all patients but one showed a positive effect. In terms of the lexical boost, the mean for the patients was 12% (range: 1% - 27%), which was similar to the mean for controls (13%, range: 0% - 36%) (see Figure 1.2b). When comparing lexical boost effects in single patients to the control sample, all differences were non-significant (all $p > .32$). At the group level, the difference between the mean for patients and controls was far from significant ($t(21) = .25, p = .80$)\textsuperscript{5}.

\textsuperscript{5} It should be noted that although most patients had mild verb naming deficits (as shown in the verb naming task; see Table 1.1), it did not seem to affect their lexical boost: patients’ verb naming accuracies were not correlated with the lexical boost effects, $r(10) = .34, p = .28$. This was not surprising given that the verb was presented to participants before producing the target sentence. Also, patients’ impairments in verb processing were not severe: in another index of verb processing in the QPA analysis (Rochon et al., 2000), most patients were normal in the proportion of verbs to nouns (Table 1.1), and this measurement was not correlated with lexical boost either, $r(10) = .15, p = .64$. The two patients (WC and GP) who had the lowest scores on the verb naming task showed a 19% and 5% lexical boost, respectively. Similarly, scores on the two noun processing tasks were also not correlated with the lexical boost, $r < .32, ps > .31$. 

Figure 1.2 Syntactic priming and lexical boost effects in Exp. 1.1

a. Individual syntactic priming effects in the different-verb condition in transitive trials (the lines indicate mean scores).

b. Individual lexical boost effects in transitive trials (the lines indicate mean scores).
Interestingly, the correlation between the size of syntactic priming in the different verb condition and the lexical boost effect was near zero for both the patient group and the control group ($r(10) = .02$ and $r(9) = .07$ respectively, and $r(21) = .05$ when combining data from the two groups), which is suggestive of different sources for the two effects. I will return to this issue in the general discussion. Importantly, however, patients’ lexical boost effects were not correlated with their STM capacities for word lists, with correlations going (non-significantly) in the wrong direction for category probe span, $r(10) = -.04$, $p = .90$, and for the phonological STM composite score, $r(10) = -.30$, $p = .35$. By way of illustration, RK showed a strong lexical boost effect (27%) while GP and RR showed much weaker effects (5% and 1% respectively), but GP and RR performed substantially better than RK on most STM measures. In addition, among the eight control speakers for whom STM capacities were tested, there was also no significant correlations between lexical boost effects and any STM measure: category probe span, $r(6) = -.40$, $p = .33$; and phonological STM composite score, $r(6) = .29$, $p = .49$. For full statistics of correlation analysis in the patient and control groups, please refer to Appendix D and Appendix E.

Moreover, the lexical boost did not correlate with STM for sentences. For sentence repetition, there was a non-significant negative correlation between patients’ ability to correctly repeat the prime sentences overall, $r(10) = -.22$, $p = .48$, and to correctly repeat the verb in the prime sentence, $r(10) = -.23$, $p = .48$, which was expected based on the findings for list memory, given the dependence of sentence repetition principally on phonological and semantic STM for word lists. For the sentence STM task, the lexical boost did not correlate significantly with the ability to detect verb differences, $r(7) = .29$, $p = .45$, to detect structure differences, $r(7) = .37$, $p = .33$, nor with overall performance, $r(7) = .38$, $p = .32$. Appendix F shows plots of the strongest
correlations in patients. Admittedly, these moderate correlations may potentially turn out to be reliable with a larger sample size of participants. However, a detailed examination of individual patient data confirmed that the lexical boost cannot rely solely on STM capacities. For example, Patient FW had the lowest scores on most of the sentence STM measures, but showed a robust lexical boost of 12%. By contrast, MK and DW did much better than FW on all sentence STM measures, but showed lexical boost effects of only 4% and 2%.

It should be noted that among patients there was no relationship between any measure of STM capacity and syntactic priming in the different verb condition either, with all correlations in the wrong direction: category probe span, $r(10) = -.15$, $p = .94$; phonological STM composite score, $r(10) = -.49$, $p = .11$; accuracy in repeating primes, $r(10) = -.17$, $p = .61$; accuracy in repeating verbs in prime sentences, $r(10) = -.21$, $p = .50$; ability to detect verb differences, $r(10) = -.70$, $p = .037$; ability to detect structure differences, $r(10) = -.48$, $p = .19$; and the overall $d'$ scores in the sentence STM task, $r(10) = -.49$, $p = .18$. These findings are thus in line with prior findings suggesting that explicit memory is not needed for abstract syntactic priming (e.g., Ferreira et al., 2008).

Because of the limited double object sentence production for many patients in Experiment 1.1, data from transitive trials was focused on. However, a task which could potentially elicit more DO target sentences in patients would allow us to obtain converging evidence about the relationship between STM and lexical boost in dative trials, which have been used in most syntactic priming studies. A word array paradigm used by Cho-Reyes, Mack, and Thompson (2016) was shown to be effective in eliciting DO production in aphasic patients. Therefore, Experiment 1.2 used the word array paradigm to further investigate lexical boost in dative trials in patients.
Experiment 1.2 Word array task

Method

Experiment 1.2 used a word array paradigm adapted from Cho-Reyes et al. (2016) to investigate syntactic priming and lexical boost effects in dative trials. As was discussed before, using a word array paradigm may not only minimize the influence of a pictorial event structure on the word order, but also reduce patients’ processing load by presenting words on the screen. Both factors could potentially boost the use of DO sentences compared to PD sentences, making it possible to explore the lexical boost in dative trials. Furthermore, utilizing dative trials in Experiment 1.2 also could potentially provide a larger effect than transitive trials in Experiment 1.1, given that a meta-analysis has shown that dative sentences were about twice as powerful as transitive sentences in inducing syntactic priming effects (Mahowald et al., 2016).

Different from Cho-Reyes et al. (2016), which only examined the abstract syntactic priming effects in dative sentences, the current experiment included the manipulation of same vs. different verb between the prime and the target sentences to explore the lexical boost. Although the focus was on dative trials, there was also a similar manipulation of the structure and the verb in the transitive trials.

Participants

A subset of eight aphasic patients who had completed the picture description task in Experiment 1.1 participated in the current experiment. There was an interval of at least a month between the two experiments. These patients were: FW, MK, MLB, WC, DW, KC, RK and GP. Patients’ mean age was 58 (range: 47-67). There were ten healthy control speakers in Experiment 1.2, of whom six had participated in Experiment 1.1, with an interval of at least two years between the two experiments. Controls’ average age was 74 (range: 61-87). On average,
control speakers received 16 years of education. All patient and control participants did the task only once.

**Materials, procedure and data analysis**

**STM measures**

Experiment 1.2 used the same STM measures as in Experiment 1.1, i.e., category probe spans, rhyme probe spans, digit matching spans, digit spans, accuracies in repeating prime sentences and verbs in the current experiment, together with $d'$ scores, accuracies in the different verb condition, and accuracies in the different structure condition in the sentence STM task.

**The word array task**

Experiment 1.2 was designed to closely match the picture description task in Experiment 1.1. The only major change in materials was that while there were more transitive trials than dative trials in Experiment 1.1, the current experiment had more dative trials. There were four lists, each list had 32 dative target sentences and 16 transitive target sentences, together with 16 filler intransitive sentences (e.g., the grey mouse was jumping). Each target sentence was paired with a preceding prime sentence, manipulated by structural sameness and verb sameness. The target sentences were the same across the four lists, but each specific target sentence was preceded by a prime sentence in one of the four conditions in each list. In each list, there was an equal number of PD vs. DO primes, and an equal number of active vs. passive primes. Half of the experimental trials had the same verb between the prime and the target sentence, the other half had different verbs. Most of the dative sentences were taken from Cho-Reyes et al. (2016), with the rest of the sentence materials either taken from Experiment 1.1, or newly created. See Appendix C for a list of sentence materials used in the current experiment. Each participant came to the lab four times to complete the four lists, with at least a four-day interval between two lists.
The task was presented by a computer using the DMDX software (Forster & Forster, 2003). The experiment starts with four practice trials. In each trial, participants heard a prime sentence like *the lawyer brought the partner the document*, and were asked to repeat the sentence. After the attempt to repeat the prime sentence, participants saw the sentence on the screen and read it aloud. They then saw the words visually presented on the screen (Figure 1.3) and were asked to orally produce a sentence using all of the words. The main verb was always presented in its inflected past tense/past participle form on the left of the screen, and the three nouns were presented on the right in a triangle fashion. Each thematic role (agent/theme/recipient) in a sentence was randomly presented in one of the triangle positions. For transitive trials, the two nouns and an adverb were presented in a triangle pattern (e.g., *the golfer was quickly cooled by the fan*). Patients took about 50 minutes to finish one list, compared to about 30 minutes with controls.

Experiment 1.2 followed the same scoring scheme and data analysis processes as Experiment 1.1. The abstract syntactic priming effect in dative trials was defined as the proportion of PD sentences out of all PD/DO target sentence responses.

<table>
<thead>
<tr>
<th>Gave</th>
<th>gift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>priest</td>
</tr>
<tr>
<td></td>
<td>orphan</td>
</tr>
</tbody>
</table>

Figure 1.3 An example sentence-eliciting stimulus for a dative sentence (*the priest gave the gift to the orphan*)
Results and discussion

Participants’ proportions of response types in target sentences were shown in Table 1.7. While patients did produce many more DO sentences than in Experiment 1.1, they produced substantially fewer passives, with 3 of the 8 patients producing 3% or fewer passive structures. Although the passive structure is less preferred than the active in English, I designed half of the transitive target sentences in the current experiment to have inanimate agents in order to promote the use of the passive construction (e.g., the golfer was quickly cooled by the fan). Passives are more likely to be used when the sentence has an animate theme and an inanimate agent (Bock, 1986; Harris, 1978), probably because animate nouns are conceptually more accessible than inanimate nouns, and are more likely to be assigned a higher-order grammatical role of “subject” (instead of “object”), which in turn results in a passive structure selected for production (Bock & Warren, 1985; McDonald, Bock, & Kelly, 1993). One possible explanation for the limited use of passives in the current experiment may be that the word array task was not as effective as the picture description task in highlighting the differences in conceptual accessibility between an animate theme and an inanimate agent, giving the participants, especially patients, less “incentive” to use the less-frequent passive structure. I therefore focused on analyzing the data from dative trials in the current experiment.
Table 1.6 Percent response types in target sentences in Exp. 1.2

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>GP</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transitives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>0.81</td>
<td>0.78</td>
<td>0.84</td>
<td>0.95</td>
<td>0.41</td>
<td>0.73</td>
<td>0.80</td>
<td>0.92</td>
<td>0.80</td>
<td>0.63-0.95</td>
</tr>
<tr>
<td>Passive</td>
<td>0.08</td>
<td>0.17</td>
<td>0.09</td>
<td>0.03</td>
<td>0.52</td>
<td>0.00</td>
<td>0.14</td>
<td>0.00</td>
<td>0.19</td>
<td>0.05-0.38</td>
</tr>
<tr>
<td>Other</td>
<td>0.11</td>
<td>0.05</td>
<td>0.06</td>
<td>0.02</td>
<td>0.08</td>
<td>0.27</td>
<td>0.06</td>
<td>0.08</td>
<td>0.01</td>
<td>0-0.05</td>
</tr>
<tr>
<td><strong>Datives</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>0.70</td>
<td>0.69</td>
<td>0.96</td>
<td>0.41</td>
<td>0.34</td>
<td>0.47</td>
<td>0.91</td>
<td>0.01</td>
<td>0.62</td>
<td>0.45-0.81</td>
</tr>
<tr>
<td>DO</td>
<td>0.16</td>
<td>0.20</td>
<td>0.01</td>
<td>0.37</td>
<td>0.59</td>
<td>0.26</td>
<td>0.08</td>
<td>0.94</td>
<td>0.36</td>
<td>0.16-0.55</td>
</tr>
<tr>
<td>Other</td>
<td>0.13</td>
<td>0.11</td>
<td>0.03</td>
<td>0.23</td>
<td>0.08</td>
<td>0.27</td>
<td>0.01</td>
<td>0.05</td>
<td>0.03</td>
<td>0-0.07</td>
</tr>
</tbody>
</table>

Table 1.7 Percent priming effects in dative trials in Exp. 1.2

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>GP</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Priming effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.02</td>
<td>-0.02</td>
<td>0.05</td>
<td>0.12</td>
<td>0.03</td>
<td>0.02</td>
<td>0.24</td>
<td>0.04-0.73</td>
</tr>
<tr>
<td>Same verb</td>
<td>-0.05</td>
<td>0.03</td>
<td>0.03</td>
<td>-0.14</td>
<td>0.10</td>
<td>0.13</td>
<td>0.10</td>
<td>0.00</td>
<td>0.31</td>
<td>0.06-0.88</td>
</tr>
<tr>
<td>Different verb</td>
<td>0.02</td>
<td>-0.03</td>
<td>0.00</td>
<td>0.10</td>
<td>0.00</td>
<td>0.10</td>
<td>-0.03</td>
<td>0.03</td>
<td>0.16</td>
<td>-0.09-0.63</td>
</tr>
<tr>
<td>Lexical boost</td>
<td>-0.07</td>
<td>0.05</td>
<td>0.03</td>
<td>-0.23</td>
<td>0.10</td>
<td>0.03</td>
<td>0.13</td>
<td>-0.03</td>
<td>0.15</td>
<td>-0.04-0.38</td>
</tr>
</tbody>
</table>
As shown by Table 1.7, controls showed an average abstract priming effect of 16%, an increase of 53% of PD responses following DO primes to 70% PD responses following PD primes. The effect was significant in the LME modelling, \( Z = 2.97, p = .003 \). There was also a significant lexical boost of 15%, \( Z = 2.75, p = .006 \), showing that the priming effect increased from 16% when the verb was not repeated between the prime and the target, to 31% when the verb was repeated from the prime to the target. For patients, apart from WC and KC, who both showed a 10% abstract priming effect, other patients showed little or no priming effect, with the mean priming effect for patients being only 2% (Figure 1.4). These findings for the patients contrasted sharply to Cho-Reyes et al. (2016), which used the same word array task to elicit target sentence production and found an average of 21% abstract priming effects in 13 aphasic patients and 27% priming effects in 13 control speakers. One notable difference in task design between the current study and Cho-Reyes et al. (2016) was that they used a secondary memory probe task, in which participants were asked after 25% of trials whether they had seen a probe word before. This memory task might have encouraged participants’ intentional maintenance of the prime sentence in their STM, which could have boosted the priming effects (Bernolet et al., 2016).

\[ ^6 \text{ANOVAs showed similar results. Followed similar procedures as in Experiment 1.1, I calculated proportions of PD responses out of all PD and DO responses in four conditions (PD/DO prime} * \text{same/different verb), and arcsine transformed these proportions as the dependent variable, with prime construction and verb sameness as the within subject and within item factors. There was a significant syntactic priming effect, } F_1 (1, 9) = 9.73, \text{MSE} = .100, p = .012; F_2 (1, 31) = 63.00, \text{MSE} = .068, p < .001. \text{The lexical boost effect was also significant, } F_1 (1, 9) = 10.95, \text{MSE} = .125, p = .009; F_2 (1, 31) = 10.32, \text{MSE} = .057, p = .003. \]
Figure 1.4 Syntactic priming and lexical boost effects in Exp. 1.2

a. Individual syntactic priming effects in the different-verb condition in dative trials in Experiment 1.2 (the lines indicate mean scores).

b. Individual lexical boost effects in dative trials Experiment 1.2 (the lines indicate mean scores).
Even compared to Experiment 1.1, the same patients generally have reduced abstract priming effects in the current experiment (7% vs. 2% on average). The fundamentally different processes involved in producing a sentence out of written words (as in the current experiment) vs. pictures (as in Experiment 1.1) may have resulted in different syntactic priming effects in the two tasks. Producing a sentence out of pictures is more similar to natural processes of sentence production, where speakers start with a clear concept of the event to be described, followed by constructing an abstract sentence structure (Bock & Ferreira, 2014; Bock & Levelt, 1994). According to an implicit learning account of syntactic priming, a similar event structure (e.g., a dative event) between the prime and the target sentences would make speakers implicitly learn from the mapping between the event and the prime sentence structure, therefore more likely to reuse the same sentence structure in describing the target event. By comparison, to make a sentence out of written words, one would have to comprehend the words and then deduce a possible event before building an abstract sentence structure to describe the event. Some of the patients took a considerable amount of time to carry out this process. Also, the determination of a possible event was more difficult in our experiment than in the Cho-Reyes et al. study, as we mixed transitive events with dative events. This process of coming up with an event structure and choosing a possible sentence structure (and the time involved) may potentially have overridden the structural influence from the prime sentence (Tooley & Bock, 2014). Although the experiment was not set up to collect speech onset latencies, the duration data of target sentences was recorded and could be analyzed. The duration was defined as the time from the onset of the word array up to the pressing of the spacebar, which indicated the end of the target sentence production and initiated the next trial. I eliminated outlier trials with durations shorter than 3 seconds or longer than 60 seconds, then calculated means and standard deviations and further
deleted RTs more than 2.5 standard deviations away from each participant’s mean. Control speakers showed an average duration time of 9 seconds. By comparison, patients took 20 seconds on average to produce a target dative sentence. Because of the low mean priming level, I did not calculate correlations with STM measures for abstract priming, as any relation would be hard to detect given the restricted range.
Table 1.8 Percent accuracy in repeating primes in Exp. 1.2

<table>
<thead>
<tr>
<th>Patients</th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>GP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td>Mean</td>
<td>Control Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence</td>
<td>0.05</td>
<td>0.04</td>
<td>0.04</td>
<td>0.55</td>
<td>0.93</td>
<td>0.39</td>
<td>0.02</td>
<td>0.77</td>
</tr>
<tr>
<td>Verb</td>
<td>0.16</td>
<td>0.27</td>
<td>0.30</td>
<td>0.91</td>
<td>1.00</td>
<td>0.63</td>
<td>0.02</td>
<td>0.88</td>
</tr>
</tbody>
</table>

In terms of the lexical boost effects, 5 out of 8 patients showed positive effects, but three patients showed negative effects, with two of them (WC and FW) outside the range of control speakers. The large negative effects with Patient WC and FW (-23% and -7% respectively) were not expected, given the robust lexical boost they showed in Experiment 1.1 (19% and 12%). This cannot be due to any deficit in the dative structure, because both patients produced sizable numbers of DO and PD target sentences (Table 1.6). Both scored over 90% correct in a word reading task (PALPA 31: imageability & frequency word reading; Kay, Lesser, & Coltheart, 1992) as part of their background testing, making it unlikely that reading deficits contributed to the findings. However, WC did very poorly on the Berndt Verb Naming test (60% correct), indicating that a deficit in verb processing might have affected her lexical boost. FW was also impaired on this verb naming task, though his accuracy of 80% was similar to several other patients. Perhaps a verb impairment affected the lexical boost in the current experiment more than in Experiment 1.1, because good processing of the verb is critical to deduce the sentence meaning in the current experiment, while in Experiment 1.1 the event could be easily comprehended in the target picture. Consistent with this hypothesis, these two patients were the slowest patients in producing sentences. Specifically, on average: FW took 31s and WC 26s, whereas the rest ranged from 13-25 s with a mean of 18. It is possible that for WC and FW, the
transient activation of the verb and the structure representations due to prime processing could have decayed considerably by the time they were constructing the syntactic structure for the target sentence, causing no lexical boost. Their syntactic priming should be less affected if we assume that syntactic priming is subserved by implicit learning, which might be less impaired in the patients and is associated with effects that are more persistent in time course (Chang et al., 2006; Hartsuiker et al., 2008). Nevertheless, STM deficits are unlikely to have had a role in causing the negative effects in these patients. Although FW was indeed one of the worst on STM tasks among patients, WC was much better. By comparison, Patient DW, who was very like WC in many STM measures, showed the second-largest lexical boost among patients. Across patients, correlations between STM measures and lexical boost effects were all in the wrong direction or nonsignificant, $-.36 < r_s < .13$, $p_s > .39$ (see Appendix D for correlation results).

For control speakers, however, phonological STM composite scores significantly correlated with the lexical boost effects, $r(8) = .68$, $p = .032$, suggesting a role for phonological STM in the lexical boost, which would be consistent with an influence of episodic STM. Lexical boost effects in control speakers also had moderate (though nonsignificant) correlations with category probe spans, $r(8) = .47$, $p = .18$. (see Appendix E for correlation analysis results, and Appendix F4 and F5 for plots of correlations). I will return to these findings in the general discussion.

**General Discussion**

Our study tested the explicit STM account of the lexical boost in syntactic priming tasks (Chang et al., 2006; Reitter et al., 2011) by examining syntactic priming and the lexical boost in patients with varying degrees of STM deficits. Despite patients’ difficulty in maintaining lexical or structural information, as evidenced by impaired performance on STM tasks using word lists
and sentences, the patients showed lexical boost effects comparable to those of healthy speakers in transitive sentences in Experiment 1.1 and most patients showed positive lexical boost effects in dative sentences in Experiment 1.2. Moreover, there was no relation between the size of lexical boost effects and STM measures in both experiments. Thus, patients’ impaired STM did not lessen the effect of lexical overlap on the choice of syntactic structure. Therefore, it seems unlikely that the lexical boost effect on syntactic priming relies on explicit STM-based maintenance of the particular sentence structure used with a specific verb.

Findings in the current study are in sharp contrast to the notion that the lexical boost results from the retrieval of structural information in STM (e.g., Chang et al., 2006; Reitter et al., 2011). As was discussed in the introduction, details of the memory processes in these models remain vague and lack further evidence. In a recent study, Scheepers, Raffray, and Myachykov (2017) speculate that speakers maintain a shallow representation of the surface structure of the prime sentence, which could include “whether the verb is followed by an animate or inanimate noun, or whether or not the sentence contained a preposition” (p.112), and processing of any content word (verb or any noun) repeated from the prime to the target sentence can provide a contextual cue making it easier for speakers to recall and reuse the prime structure, resulting in the lexical boost. For this cueing from the verb or other content words to contribute to the lexical boost, speakers would have to recall the content word and its association with the other relevant information (e.g., the “by” in passives). Even this minimal level of memory for the prime sentence would appear to be beyond the abilities of some of our patients. For example, Patients FW and GP performed very poorly in the sentence STM task in judging whether or not two adjacently presented transitive sentences of alternative structures were identical (Table 1.3). Nonetheless, FW showed a lexical boost of 12%, similar to the average effect size in control speakers, and GP showed a
lexical boost of 5%, larger than several other patients and controls who were much better in detecting structure differences between sentences in the sentence STM task. Therefore, our findings are difficult to explain by a STM account of the lexical boost.

Despite the lack of evidence for a role of explicit STM in the lexical boost, aspects of these data could be taken as support for the claim that abstract syntactic priming and the lexical boost depend on different mechanisms. Specifically, there was no correlation between patients’ or controls’ abstract syntactic priming and lexical boost effects. For instance, in Experiment 1.1, of the four patients who showed the smallest abstract priming effects (in fact, negative effects) three (WC, RK, and RI) showed lexical boost effects that were greater than the mean for controls (i.e., > 13%) whereas the fourth (DW) showed a small lexical boost (2%). In Experiment 1.2, Patient RK, who showed the largest lexical boost effect of 13%, had a negative abstract priming effect of -3%, while Patient WC showed the strongest abstract priming (10%) but the largest negative lexical boost effect (-23%). Below I consider whether other theoretical approaches can accommodate the lack of correlation between syntactic priming and the lexical boost.

According to the spreading activation model of Pickering and Branigan (1998), one might have expected a correlation between abstract syntactic priming and the lexical boost if the degree of residual activation of structure (which underlies abstract priming) is correlated with the degree of activation of the verb lemma and the links between structure and the verb (which underlie the lexical boost). To account for the present findings, one would have to assume that for both patients and control speakers there is independence in either the base level or the rate of decay of the activation of lemmas and structural representations. As discussed earlier, however, this activation approach runs into difficulty in accounting for persistent priming effects. The hybrid model by Tooley and colleagues (e.g., Tooley & Traxler, 2010) could potentially provide
an explanation for both the dissociation between abstract priming and lexical boost effects and persistent priming effects. That is, the activation component of this model could account for the dissociation between abstract priming and the lexical boost in the same fashion as proposed for the Pickering and Branigan approach whereas the implicit learning component could account for long-term persistent priming (Kaschak, Kutta, & Jones, 2011a).

An alternative approach, which does not require the assumption of differential activation or decay for lexical and structural representations, is the model proposed by Jaeger and Snider (2013), which assumes adaptation in production based on prediction errors. As discussed in the introduction, speakers adjust their predictions for different structures and the association of structures with lexical items based on exposure, which serves to facilitate communication. Because distributions of lexical recurrence and structural recurrence have different properties, in that there is greater clustering of recurrence of lexical items than structures, comprehenders may be differentially sensitive to these distribution differences for lexical and structural recurrence, resulting in a lack of association between syntactic priming and lexical boost effects.

In conclusion, Study 1 found that despite their impaired STM for words and sentences, most patients showed lexical boost effects comparable to those of controls and there was no relation between the size of their STM deficits and the size of the lexical boost effects. In addition, for both patients and controls, there was no relation between the size of abstract syntactic priming and lexical boost effects. These results imply that the lexical boost does not rely on explicit STM. Instead, these data support the idea that the lexical boost reflects non-STM-mediated processes, such as residual activation of linguistic representations, or expectation adaptation, which are likely preserved despite damage to STM processes. However, in order for these models to account for the lack of relation between syntactic priming and the lexical boost,
independence in activation or expectation processes for lexical and structural representations would have to be assumed.
Study 2

The choice of structure and processing difficulties in dative sentences

Introduction

Processing of dative sentences in different speaker groups

Speakers often have the freedom to choose one of a few sentence structures to express their ideas, but they don’t make their choices randomly. The choice of sentence structure could be affected by how easy it is to construct a certain sentence structure. For example, agrammatic patients tend to produce sentences that are short and have simplified structures (Berndt, 2001). Also, as we found in Study 1 in my dissertation, in choosing between active vs. passive structures, or DO vs. PD structures, speakers are influenced by their recent language experience and tend to reuse the same structure that has been process previously (structural priming), presumably because this structure is more readily available than alternative ones. Choosing a structure can also be influenced by lexical factors. The immediate repetition of a verb can prime speakers to reuse the same sentence structure associated with the verb (lexical boost). Speakers also tend to choose a structure that allows them to produce the more accessible word (e.g., an animate word or a noun that has been mentioned recently) early in the sentence, so that they may prefer to say he was struck by the lightning rather than the lightning struck him (Bock & Warren, 1985; Prat-Sala & Branigan, 2000). Moreover, these structural choices may interact with non-linguistic cognitive systems, as many studies found a role of STM in sentence production and comprehension (Martin & Slevc, 2014; Martin & Tan, 2015). The current study explores linguistic and non-linguistic factors behind the choice of sentence structures in speakers. I will use English dative alternations as an example to study processes in choosing a structure, because dative sentences
are a pair of syntactic alternations commonly found in English and many languages (Levin, 2008a), with many research findings providing a foundational understanding of the structures. Also, dative sentences have been the most widely sentence types in syntactic priming studies, and a deep understanding of factors affecting dative sentence processing will also inform future research using these sentences.

In English, as in many other languages, there are alternative sentence structures to express the event of transferring of an entity from one source to the other. The examples below demonstrate the two alternatives for a dative construction, Sentence (1) is a prepositional dative construction (PD) and Sentence (2) is a double object construction (DO).

(1) The teacher sent a book to the student.

(2) The teacher sent the student a book.

Table 2.1 lists some terms that I will use in my dissertation when discussing the dative alternations. Both constructions describe an event in which the agent (the teacher) transferred the theme (a book) to the recipient (the student). Some researchers argue that DO and PD are associated with distinct, though similar meanings (Goldberg, 1995; Hale & Keyser, 2002), with DO expressing the transfer of possession and PD describing a motion of an object, whereas other researchers believe that these distinctions are subtle and not applicable to all dative alternatives (Baker, 1988; Levin, 2008b). Importantly, these accounts do acknowledge the fact that speakers frequently use both structures interchangeably to describe the same idea. In my dissertation, I will assume that the dative alternations share very similar, if not identical meanings, and the two constructions have the same degree of conceptual complexity. However, whether the two structures are comparable in syntactic complexity is not clear.
Table 2.1 Terms for the dative constructions

<table>
<thead>
<tr>
<th></th>
<th>Prepositional dative construction (PD)</th>
<th>Double object construction (DO)</th>
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<tbody>
<tr>
<td><strong>Example</strong></td>
<td><em>The teacher sent a book to the student.</em></td>
<td><em>The teacher sent the student a book.</em></td>
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<tr>
<td><strong>Argument/information structure</strong></td>
<td>Agent</td>
<td>Theme</td>
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<tr>
<td><strong>Grammatical/syntactic structure</strong></td>
<td>Subject</td>
<td>Direct object</td>
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<tr>
<td><strong>(thematic roles)</strong></td>
<td></td>
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<td><strong>(grammatical roles)</strong></td>
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The relationship of the two dative syntactic structures has been extensively discussed in research adopting formal linguistic approaches. Some researchers argued that one of the dative structures is a “base structure” and the other is derived from this base structure. The derived structure was generally believed to be syntactically more complex than the base structure. For example, Chomsky (1975), Fujita (1996) and Larson (1988, 1990) argued that DO is syntactically derived from PD while other research held the opposite view (Aoun & Li, 1989). Recent developments in formal linguistics have shifted from the transformational approach to a non-derivational view, arguing that DO and PD are two independent structures that are not transformationally related (Harley, 2002). Compared to PD, DO is syntactically more complex because it has one more layer of abstract syntactic projection that corresponds to a meaning component of HAVE, denoting the recipient’s possession of the theme as a result of the verb action (Beck & Johnson, 2004; Bowers, 2002). To illustrate this additional meaning component, Sentence (1), *the teacher sent a book to the student*, can be expressed as:

[the teacher’s sending the book] CAUSE [BECOME [a book is AT the student]]

While the double object Sentence (2), *the teacher sent the student a book*, is expressed as:

[the teacher’s sending the book] CAUSE [BECOME [the student HAVE a book]]

Correspondingly, the syntactic structures of the two sentences are shown below in Figure 2.1.
Figure 2.1 Syntactic structures of the two dative alternations

(a) Syntactic structure of the teacher sent a book to the student

(b) Syntactic structure of the teacher sent the student a book
There is some empirical evidence both from the literature (Caplan & Futter, 1986; Gibson, Sandberg, Fedorenko, Bergen, & Kiran, 2015) and from our own lab (see Exp. 1) showing that at least in some circumstances, speakers may have more difficulty processing DO than PD. I will review relevant findings and discuss potential factors that are related to different degrees of processing difficulties with the two dative constructions.

**Dative sentence production in Study 1**

In Experiment 1.1, most aphasic speakers had great difficulty in repeating DO primes and producing target sentences in DO in response to target pictures. Many of them had very little spontaneous production of DO, even though half of the dative target pictures followed DO primes. Healthy age-matched control speakers, while almost always being able to repeat DO primes correctly, nonetheless showed low proportions of DO production. As shown in Table 2.2 and Figure 2.2, the average of 13% of DO responses in both patient and control groups. The low proportion of DO production in patients and control speakers in this task was surprising, given that pictures depicting dative events are the most frequently used type of target pictures to elicit target sentences in syntactic priming studies, with healthy young speakers always producing on average sizable proportions of sentences in both dative alternations, although usually there are more PD than DO responses. For example, in the seminal syntactic priming study by Pickering and Branigan (1998) with similar experimental manipulations as in Study 1 reported here, young speakers produced 29% of dative target sentences in the form of DO, while producing 71% in the PD form. To verify that there was nothing unusual about our materials and design, I tested 28 undergraduate subjects in our paradigm. For these student participants, the average proportion of DO target sentences was 36% (though there was a considerable range there as well, with 3 of 28 producing no double objects; see Figure 2.2). One factor that could be related to the different
percent DO production among groups may be STM capacities, as older adults have smaller capacities than younger subjects (Naveh-Benjamin, Cowan, Kilb, & Chen, 2007; Salthouse & Babcock, 1991). Patients’ proportions of DO production had a statistically significant relationship with phonological STM, $r(10) = .64$, $p = .024$ (Figure 2.3a). Semantic STM also showed a moderate though nonsignificant relationship with proportions of DO production, $r(10) = .41$, $p = .186$ (Figure 2.3b). I will discuss the possible role of STM in DO production later in Exp. 2.1, in the section titled “Potential factors that affect DO sentence processing”.
Table 2.2 Percent response types in dative target sentences in Exp. 1.1

<table>
<thead>
<tr>
<th></th>
<th>FW</th>
<th>MK</th>
<th>MLB</th>
<th>WC</th>
<th>DW</th>
<th>KC</th>
<th>RK</th>
<th>LC</th>
<th>RI</th>
<th>PP</th>
<th>GP</th>
<th>RR</th>
<th>Control Mean</th>
<th>Control Range</th>
<th>UG Mean</th>
<th>UG Range</th>
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<tr>
<td>Datives</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>0.89</td>
<td>0.77</td>
<td>0.91</td>
<td>0.81</td>
<td>0.46</td>
<td>0.69</td>
<td>0.92</td>
<td>0.93</td>
<td>0.90</td>
<td>0.77</td>
<td>0.70</td>
<td>0.27</td>
<td>0.83</td>
<td>0.59-0.98</td>
<td>0.55</td>
<td>0.19-1</td>
</tr>
<tr>
<td>DO</td>
<td>0.05</td>
<td>0.06</td>
<td>0.01</td>
<td>0.05</td>
<td>0.39</td>
<td>0.31</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.19</td>
<td>0.50</td>
<td>0.13</td>
<td>0.02-0.38</td>
<td>0.36</td>
<td>0.0-0.81</td>
</tr>
<tr>
<td>Other</td>
<td>0.06</td>
<td>0.17</td>
<td>0.08</td>
<td>0.14</td>
<td>0.16</td>
<td>0.00</td>
<td>0.07</td>
<td>0.10</td>
<td>0.20</td>
<td>0.11</td>
<td>0.23</td>
<td>0.03</td>
<td>0.00</td>
<td>0.0-0.16</td>
<td>0.09</td>
<td>0-0.69</td>
</tr>
</tbody>
</table>

* UG = undergraduate participants

Figure 2.2 Distributions of percent DO responses in different participant groups in Exp. 1.1
a. Relationship between phonological STM composite scores and proportions of DO production in Experiment 1.1

b. Relationship between semantic STM (category probe spans) and proportions of DO production in Exp. 1.1

Figure 2.3 Plots of relationship between phonological/semantic STM and percent DO production in Exp. 1.1
Evidence suggesting for a possible role of STM in making DO sentences more difficult to produce than PD was also found in Exp. 1.2. As was discussed in Study 1, there were two possible explanations why the word array paradigm was more efficient in eliciting DO production from participants. One possibility was that in Exp. 1.1, the order of objects in a target picture aligned with the word order in the PD structure, possibly resulting in a bias toward choosing PD vs. DO in describing the picture. Randomizing the positions of words on the screen in the word array paradigm in Exp. 1.2 might have reduced this influence. I will discuss this in more detail in the section of “Potential factors that affect DO sentence processing” in Study 2.1. Another possibility for more DO production in Experiment 1.2 was that having the words presented on the screen reduced potential STM cost with producing DO sentences, because participants did not have to maintain any word in their STM during production. Results from Exp. 1.2 did confirm that both patients and controls increased their DO production, producing 33% and 36% target dative sentences in the DO form, respectively. Also, as was found in Exp. 1.1, patients’ percent DO production in Exp. 1.2 was related to semantic STM ($r(6) = .74$, $p = .037$) and phonological STM (though nonsignificantly: $r(6) = .62$, $p = .104$), showing again the possible role of STM in choosing alternative dative structures in sentence production.

The role of STM in control speakers, however, was less clear. The only STM measure that significantly correlated with percent DO production in Exp. 1.1 or Exp. 1.2 in control speakers was the phonological STM composite score, which correlated with percent DO production in Exp. 1.2, $r(8) = .73$, $p = .017$. Other correlations were nonsignificant and sometimes in the wrong direction, $-.47 < rs < .16$, $p > .24$. The less strong evidence in control speakers was not unexpected, given that healthy control speakers, with much better STM capacities than patients (as shown in Table 1.1), may not be affected by a potential STM cost
with producing a DO structure to the same extent as patients. One might wonder why control speakers’ much better STM capacities did not result in a much larger mean proportion of DO production than the patient group mean in Study 1. A closer examination of the data showed that patient group means were driven by outliers from patients with near-normal STM capacities in both experiments. For example, in Exp. 1, Patient RR produced 55% dative sentences in DO, much higher than the second largest one, which was 39%. In Exp. 2, Patient GP’s proportion of DO production was 94%, compared to the second-largest one of 59%. RR and GP had the best semantic STM among patient participants, with category probe spans within the control range (see Table 1.1). Also, their phonological STM measurements were within or close to the control range. Eliminating these two patients, the mean proportions of DO production in patients were then much lower than controls, 9% vs. 13% in Exp. 1.1, and 24% vs. 36% in Exp. 1.2. Admittedly, the proportions of DO production in Study 1 were influenced by syntactic priming, therefore making the tasks not ideal for measuring the baseline capacities of dative sentence processing. Some confounding factors may also have encouraged the production of PD instead of DO, and these factors might have different degrees of effects on the three participant groups, calling for cautions in interpreting group differences in percent DO production. Apart from the order of object in the visual scene in Exp. 1.1, which promoted a word order in production similar to that in PD, lexical features may also have played a role. For example, in Exp. 1.1, recipient names often shared semantic features, with most of them being profession names, e.g., “sailor”, “swimmer”, “diver”, “pirate”, “doctor”, “nurse”. This may have made it difficult for participants to distinguish among names and retrieve the correct word (Crowther & Martin, 2014; Schnur, Schwartz, Brecher, & Hodgson, 2006). A result of the difficulties with retrieving recipient nouns might be that participants were more likely to retrieve theme nouns and produced
the theme earlier, resulting in a PD structure. Furthermore, this semantic interference effect may be stronger in patients and control participants than in young participants in Exp. 1.1, because all patient and control participants completed at least four lists of the experiment, with some of them even having completed two rounds of the testing, with eight lists in total for one participant. By comparison, each young participant only completed one list. Therefore, there could have been more cumulative semantic interference effects for patient and control speakers, affecting their DO production. I will discuss more factors that could have inhibited the use of DO structure for participants in Exp. 1.1 in the discussion section of Study 2.2.

As a summary, findings in Study 1 relating to dative sentence processing showed that many patients had difficulty in producing DO sentences, and this difficulty seems to be related to STM capacities. Control speakers also produced fewer DO sentences than young speakers in Exp. 1.1, but in general produced more DO than patients, as was shown in Exp. 1.2 and when comparing with most patients in Exp. 1.1. However, more testing was needed to study dative sentence processing in experimental paradigms eliminating confounds in Study 1. In Study 2, three comprehension and one production task will be reported to study dative sentence processing in both patients and control speakers. STM measurements were collected from all patients and most control speakers depending on their availability to explore the role of STM in dative sentence processing in both groups. However, as was discussed above, more effects were expected from patients than controls, because STM cost associated with DO should affect patients with STM deficits more than control speakers. Also, it would be difficult to explore the role of STM in sentence processing if control speakers show sentence processing performance at the ceiling level, with little individual differences. As has been found in Study 1, control speakers made few errors in repeating dative prime sentences, making it reasonable to predict
that the additional processing cost with DO may only be reflected in control data when a structural choice between DO vs. PD has to be made, as in a production task; whereas in repetition or comprehension task in which the choice of structure is not an issue, control speakers may not show apparent difficulty in processing DO vs. PD sentences. There have been only a few previous studies addressing differences in processing difficulties of DO vs. PD sentences in patient or older speakers, though there were more evidence found in corpus studies and child language research. I will review relevant findings in the next section.

**Processing of dative alternations: Evidence from the literature**

Although anecdotally, some researchers of language disorders have noted that aphasic patients often show difficulty in processing DO vs. PD (M. Dickey, personal communication, March, 2017; M. Linebarger, personal communication, November, 2016), there have been only two empirical studies providing evidence on this point, both testing comprehension rather than production. One is a case study by Caplan and Futter (1986), which found that an agrammatic patient had great difficulty understanding DO sentences. The patient consistently acted out six DO sentences like *the monkey gave the elephant the frog* as PD structures (that is, acting out the recipient as the theme and vice versa), but acted out all PD sentences correctly. It was concluded that the patient tended to interpret the first noun in the sentence as the agent, and the noun immediately following the verb as the theme, making her misinterpret all DO sentences and some passive sentences in the study. In a recent study, Gibson et al. (2015) found in an act-out task that both aphasic patients and older control speakers made many more errors on DO than PD sentences. The authors speculated this may be because DO rarely occurs with two full NPs after the verb (presumably based on corpus evidence from Bresnan (2007), which was cited in the paper), causing participants to have more difficulty processing DO compared to PD sentences.
However, a close examination of the evidence from corpus studies showed that while there are indeed far fewer DO sentences with two full NP objects than DO sentences with a pronoun recipient before a lexical NP (Bresnan, 2007), comparing between DO and PD, both structures are equally frequent in spoken language when the two objects are full NPs (Bresnan et al., 2007, p. 89; see below for further details). Therefore, construction frequency alone cannot be the only factor to account for the processing difficulty with DO sentences that have full NP recipients.

Studies of children speaking English also found that with full NP recipients, DO sentences are more difficult to process than their PD counterparts in comprehension, though with pronoun recipients, the DO structure was produced more frequently than PD. Developmental studies usually found in experimental settings that children speaking English have more difficulties in comprehending or imitating DO than PD (Cook, 1976; Osgood & Zehler, 1981; Roeper, Lapointe, Bing, & Tavakolian, 1981), and have a preference for choosing PD over DO in production (Conwell & Demuth, 2007). However, corpus studies found that DO is acquired significantly before PD (Snyder & Stromswold, 1997), and by the age of three, the majority of dative sentences are produced in the DO structure (Campbell & Tomasello, 2001). The discrepancies between these studies may lie in the different types of nouns used after dative verbs. Experimental studies that found a processing disadvantage with DO in children used sentences with full NPs, while corpus studies showing early acquisition of DO and more production of DO over PD often showed predominant use of pronoun recipients (e.g., *Mom, give me the toy!*). Perhaps what makes children produce more DO sentences is that there are more pronoun recipients in children’s spoken language than full NP recipients. In line with this possibility, evidence has been found in the corpus that children are indeed much more likely to
produce pronoun recipients in DO rather than PD sentences (de Marneffe, Grimm, Arnon, Kirby, & Bresnan, 2012).

For healthy adult English speakers, there is no evidence that either dative alternation is more difficult for them to process, although adult second language learners of English do show difficulty in learning the DO structure (Mazurkewich, 1984). Corpus studies confirmed that both dative structures are commonly used in English, with the DO structure actually occurring more frequently than the PD structure in American spoken English. An analysis of the British Component of International Corpus of English showed that in spoken British English, 58% of sentences are in DO and 42% are in PD; and in written British English, 47% of sentences are DO and 53% are PD (Gries, 2005). Bresnan et al. (2007) shows that 79% of dative sentences are DO in the Switchboard corpus (based on American telephone conversations), and 62% of datives are DO in the Wall Street Journal corpus. On the surface, these data appear to contradict many patients’ reluctance to produce DO sentences in Experiment 1.1, and are also inconsistent with young speakers’ much higher proportions of DO vs. PD productions in response to pictures. But a closer examination of the data in the corpuses again reveals a similar pattern of the interaction between the type of recipients and structure frequency as was found in child language production. Bresnan et al. (2007) showed that, when the objects in a dative sentence are full NPs, the proportion of DO vs. PD is comparable: 49% vs. 51% in the Switchboard corpus and 55% vs. 45% in the Wall Street Journal corpus (p.89). However, a full NP recipient is 3.22 times more likely to be in a PD than a pronoun recipient in both corpuses (p.83), so a pronoun recipient should be far more likely to be used in DO rather than PD. The Switchboard corpus has a larger overall proportion of DO sentences than the Wall Street Journal corpus partly because the percentage of pronoun vs. full NP recipients in dative sentences in that corpus is almost five times as much as
that in the Wall Street Journal corpus (p.89). In sum, while DO and PD are equally frequent in spoken English when the recipient is a full NP, DO is much more frequently used than PD when the recipient is a pronoun.

Why would healthy adult and child speakers prefer to choose DO vs. PD in production when there is a pronoun recipient, but not so when the recipient is a full NP? The preference for DO with pronoun recipients may also come from the tendency to produce more accessible information earlier in the sentence (Bock & Warren, 1985; McDonald et al., 1993; Tanaka, Branigan, McLean, & Pickering, 2011), with given information that has been mentioned previously in the discourse put before new information (Fillmore, 1968), and shorter words before longer words (Hawkins, 1994; Wasow, 2002) in sentences. The pronoun usually refers to given information, and tends to be shorter and more frequent than a full NP, and is therefore more accessible, resulting in it being produced before a full NP. Therefore, when the entity referred to by the pronoun is the recipient, producing it first will result in a DO rather than PD structure. The preference for a producing a DO sentence with a pronoun vs. full NP recipient may also be related to potential comprehension difficulties with full NP objects in a DO sentence, reflecting speakers’ tendency to choose a construction which is more easily understood by listeners (Hsiao & Macdonald, 2016; Macdonald, 2013). It is possible that without any grammatical cue like “to” in the DO to mark the grammatical functions of the direct object, it can be difficult to parse a string of two full NPs after the dative verb in a DO (e.g., the zookeeper gave the seal the fish) (Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Snyder & Stromswold, 1997; Stowell, 1981). A pronoun recipient may help to differentiate itself from the following full NP.
The use of full NPs rather than pronoun recipients could have played a role in limiting the use of DO in patients and old control speakers in Experiment 1.1. Participants in Exp. 1.1 almost always use full lexical NPs to refer to objects in the picture. In this sense, promoting the use of pronoun recipients may increase their production of DO. However, as I mentioned before, construction frequency cannot be the only cause of speakers’ processing difficulties with DO vs. PD sentences that have full NP recipients, because DO is at least as frequent as PD (if not more) when the recipients are full NPs (Bresnan et al., 2007). Then, what other factors make DO especially difficult to process for children, older adults and aphasic speakers? The aim of Study 2 is to explore linguistic and non-linguistic factors that could possibly affect dative sentence processing making DO structures more difficult than PD structures. Experiments 2.1a-c mainly tapped language comprehension to examine syntactic and semantic aspects of dative sentence processing, and their interactions with language experience and STM constraints. Experiment 2.2 explored various factors that may affect dative sentence production in a discourse context.

**Shared syntax between sentence production and comprehension**

Study 2 included comprehension experiments, under the guiding assumption that syntactic processes, or grammatical encoding/decoding in two modalities share the same language representations. Although traditionally, psycholinguistic research has generally studied sentence processing in these two modalities separately, there is a growing consensus that there are unified syntactic processing principles in comprehension and production. For example, in the production-distribution-comprehension (PDC) account (Hsiao & Macdonald, 2016; Macdonald, 2013), sentence production and comprehension are sensitive to linguistic distributions, which are shaped by language usage over numerous instances of utterances from all speakers and reflect various principles adopted by the speaker to mitigate cognitive burdens during sentence
production. Listeners learn these principles through language experience, and take advantage of these principles to facilitate sentence comprehension. Three major processing principles are: easy first, interference avoidance and structure reuse. For instance, speakers are more likely to retrieve easily-accessible words (e.g. animate words or shorter words) first, and put them in earlier syntactic positions (Bock & Warren, 1985; Branigan, Pickering, & Tanaka, 2008; McDonald et al., 1993; Tanaka et al., 2011). Similarly, comprehenders prefer sentence structures with easier-to-process words in earlier positions (Bresnan, 2007). The principle of structure reuse is also supported by extensive evidence from syntactic priming studies showing that speakers can be influenced in their choice of sentence structure during production either by sentences that they comprehended or produced previously. Critically, no effect of prime processing modality on syntactic priming has been found across studies (Mahowald et al., 2016). In a similar fashion, comprehending or producing a prime sentence can also facilitate comprehender’s understanding of similar sentence structures (see Tooley & Traxler, 2010 for a comprehensive review), and the priming effects in comprehension and production emerge under similar circumstances, and are similar in strength (Tooley & Bock, 2014). If syntactic representations decoded by comprehenders are fundamentally different from sentence structures encoded and produced by speakers, it would be difficult to explain the parity of structural persistence in the two modalities. Moreover, there is evidence that sentence production and comprehension involve the same neurobiological basis. Kempen (2014) proposed an amodal grammatical processor (“the Unification Space”) that operates morphosyntactic unification processing that is likely to be associated with Broca’s area, and lexical, conceptual and referential processing probably subserved by superior/medial temporal areas. Consistent with this proposal, hearing or speaking the same syntactic structure caused repetition suppression effect in the same brain regions,
namely left IFG and left posterior MTG Menenti et al. (Menenti et al., 2011). Two syntactic priming studies found that between-modality syntactic priming was subserved by the same brain regions (left IFG and left MTG) as within-modality priming, and the repetition suppression effects were equally strong for within- vs. between-modality priming (Segaert, Kempen, Petersson, & Hagoort, 2013; Segaert, Menenti, Weber, Petersson, & Hagoort, 2011). Consistent evidence also comes from neuropsychological studies, with agrammatic patients typically showing co-occurrence of agrammatic speech, and asyntactic comprehension, characterized by simplified sentence structures and grammatical morpheme errors in sentence production, and difficulties in comprehending complex sentences. However, notable exception of patient case have also been reported that patients with agrammatic speech demonstrated normal sentence comprehension (Caramazza, Capasso, Capitani, & Miceli, 2005; Caramazza & Hillis, 1989; Kolk & Van Grunsven, 1985; Miceli, Mazzucchi, Menn, & Goodglass, 1983; Nespoulous et al., 1988), showing that performance on sentence tasks in different modalities can be quite different. I will discuss possible explanations of this disparity below.

Assuming shared syntax in sentence processing should not ignore fundamental differences between sentence comprehension and production. For example, sentence processing in the two modalities goes in opposite directions, with speakers starting with an abstract idea and having to find words to express what they want to say whereas comprehenders have to go through word-by-word comprehension processing to deduce speakers’ intentions (Tooley & Bock, 2014). Also, processing demands may be different in the two modalities, with sentence comprehension in some circumstances arguably easier than sentence production because redundant information in the sentence and discourse context helps comprehenders to achieve their goal by relying on shallow processing (Sanford & Sturt, 2002). Some studies showed that
comprehenders adopt a “good-enough” interpretation of the sentence without fully decoding all information in it (Christianson, Williams, Zacks, & Ferreira, 2006; Ferreira, Ferraro, & Bailey, 2002; Ferreira & Patson, 2007; Karimi & Ferreira, 2016). By comparison, producing a sentence without any error requires perfect performance at all levels of sentence processing. Differences in processing demands across modalities and in different tasks could in part account for some seemingly dissociated patterns of performance found in agrammatic patients. For example, some patients did well in sentence-picture matching tasks and in judging the grammatical accessibility of sentences (Caramazza & Hillis, 1989; Nespoulous, et al., 1988), though they showed typical inflections errors often found in agrammatic aphasics in sentence production. However, Wilson and Saygin (2004) argued that ungrammatical sentences in the above two studies involved more than one error in each sentence, making it much easier for patients to judge the sentences, which allowed patients to do well in the task even if they failed to detect some errors. Consistent with this explanation, Wilson and Saygin (2004) studied grammaticality judgment abilities of twenty-two aphasic patients and found that most of them scored very poorly in the task. The authors argued that the subtlety of the errors in the ungrammatical sentences used in their task increased task difficulty, which was the major reason for the discrepancy in the performance of their patients and agrammatic patients who did well in grammaticality judgment tasks but not in other grammaticality tasks in other studies (e.g. Linebarger, Schwartz, & Saffran, 1983; Wulfeck & Bates, 1991).

Moreover, there can be more independence in lower levels of language processing, e.g., between speech execution and perception systems (Hickok & Poeppel, 2007; Pulvermüller et al., 2006). Martin, Lesch and Bartha (1999) proposed a separation between input phonology representations activated during language comprehension and output phonology representations
encoded during language production. In this sense, patients with output phonology impairments can show selective impairments in speech but not in comprehension. Deficits in phonological processing can impair patients’ production of morphemes (Dickey, Milman, & Thompson, 2008; Miceli, Capasso, & Caramazza, 2004). Therefore, some patients’ morphological errors in their agrammatic speech can be attributed to a deficit in output phonology, which would not affect their structural decoding in sentence comprehension. On the other hand, there are also patients with selective deficits in input phonology affecting comprehension but not production. Pure word deafness patients, for example, have deficits in speech perception despite normal hearing abilities and language production (e.g. Goldstein, Brown, & Hollander, 1975; Slevc, Martin, Hamilton, & Joanisse, 2011).

As a conclusion, both neurotypical and patient studies showed that syntactic representations are shared between comprehension and production. Syntactic processing during grammatical encoding and decoding are also shared, though sentence comprehension and production can differ in other processes like phonological processing, and differences in task processing demands often sometimes result in unbalanced performance in sentence comprehension vs. production. In Study 2 of my dissertation, both sentence comprehension and production tasks were used to explore factors that affect difficulties in comprehension and structure choices in production. The guiding assumption is that if these factors tap core syntactic processing, e.g., assigning/decoding grammatical functions and thematic roles, or mapping between these roles, then these factors should be amodal, affecting both sentence parsing in dative sentence comprehension and the choice of structure in dative sentence production. However, given the notable differences in processing at other levels between sentence comprehension and production discussed above, and potential differences in task demands, it is
expected that the effects resulting from the same factor may not always be comparable in comprehension vs. production tasks. I will discuss this again when different effects between modalities occur in the current study.
Study 2.1

Processing difficulties with double object sentences

Study 2.1 used three tasks to examine different factors that could potentially affect participants’ processing of dative sentences. These experiments were largely exploratory in nature, because processing difficulties with DO vs. PD sentences have not been fully confirmed in literature and the hypothetical factors behind these possible difficulties are also mostly lack supporting evidence. Although as discussed before, there has been some empirical evidence from several studies showing that participants with more limited language processing abilities and cognitive resources than young adult speakers may have difficulties in processing DO sentences vs. PD sentences, these findings are limited to dative constructions with full NP objects, and are sometimes incidental observations in studies with research questions not focusing on dative sentence processing. Importantly, experimental designs in past studies did not address important findings from corpus studies and formal linguistics, and there was no finding confirming any factor that could cause processing difficulties with DO vs. PD. In the current study, I will discuss possible factors affecting language users’, especially aphasic patients’ processing of dative alternations, the experimental manipulations examined these factors, and the relevant results and implications.

Potential factors that affect DO sentence processing

*Grammatical knowledge vs. language use*

Early research in aphasic patients’ sentence processing emphasized the algorithmic knowledge of syntactic structure and assumed that agrammatic patients had deficits in syntactic knowledge of
rules that determine grammatical structures (Caramazza & Zurif, 1976; Berndt & Caramazza, 1980). More recent usage-based approach of aphasic sentence processing incorporate heuristic processes that involve non-syntactic processes, including the use of lexical semantic information, word order, contextual information and most importantly, frequency of structures (Gahl & Menn, 2016), and therefore attempts to understand aphasic deficits from a “multifactorial, processing-based” standpoint (Menn & Bastiaanse, 2016). Similarly, sentence processing research in normal speakers has also contrasted two different approaches, a traditional one which argues that some sentences are inherently more difficult to process because of their syntactic complexities (Garnsey, Tanenhaus, & Chapman, 1989; Hickok, Canseco-Gonzalez, & Zurif, 1992; Sussman & Sedivy, 2003), and another asserting that language experience determines relative difficulties with certain constructions (Goldberg, 2003; Hsiao & Macdonald, 2016; Levy, 2008; MacDonald, Pearlmutter, & Seidenberg, 1994). These two schools of approaches make different predictions about language users’ difficulty in processing DO. A grammar-based approach would argue that aphasic patients and even control speakers who had limited production of DO sentences may be impaired or weak in parsing/constructing the DO structure, probably because DO constructions involve more complex syntactic operations (Beck & Johnson, 2004; Bowers, 2002; Hickok, Zurif, & Canseco-Gonzalez, 1993). According to this view, speakers are predicted to have a general disadvantage in processing all types of DO sentences vs. PD sentences, both in comprehension and production. A usage-based approach, however, would argue that although syntactic complexity may play a role, structure frequency conditioned on lexical items should be a more important factor affecting dative processing in patients. Corpus data shows that the frequency of DO vs. PD in spoken language changed dramatically depending on the type of the recipients: DO and PD are equally frequent when both objects are full NPs, whereas there are far
more DO than PD sentences when the recipients are pronouns (e.g., *the teacher sent her a book*), driving the overall proportion of DO in the Switchboard corpus to 79% (Bresnan et al., 2007). Therefore, the usage-based approach predicts that despite any potential deficit of aphasic patients in their syntactic knowledge of the DO structure, they should perform better in processing the more frequent type of DO structures that have pronoun recipients and do more poorly for DO structures with full noun recipients. Experiment 2.1a used a sentence repetition task to explore if patients would perform better on the more frequent structure of DO with pronoun recipients. Experiment 2.1b manipulated the same factors in a grammaticality judgment task and directly tested whether grammatical processing of DO is impaired in some patients or weak in some control speakers. I will elaborate on the experimental design in a subsequent section (see “design and research questions in Experiment 2.1a and 2.1b”).

**Semantic integration of the dative verb with the theme vs. the recipient**

Beyond knowledge and experience of syntactic structures, the relationship between the dative verb and its arguments may also potentially affect dative sentence processing. In Study 1, in which aphasic patients had difficulty repeating and producing DO, I conducted post-hoc informal interviews with three patients (LC, RI and RK). All of them reported that they preferred PD to DO sentences because they wanted to put the verb and the direct object together. RI and RK even rejected DO because they believed it was ungrammatical. RK, for example, stated that *the monk sent the ballerina a jug* was incorrect because “you cannot send the ballerina, you can only send a jug”, and “only a jug can be sent, a ballerina cannot be sent”\(^7\). These statements reflect the fact

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\(^7\) Interestingly, when presented a sentence like *the monk sent her a jug*, using a pronoun recipient, Patient RK stated that it was correct.
that conceptually the action directly acts upon the theme (thus the term “direct” object), but not the recipient. It is possible that putting the verb and the direct object in adjacent syntactic positions in PD helped patients’ fast semantic integration of the two content words during sentence comprehension. In sentence production, the word order in PD may also be consistent with patients’ sequential planning before speaking, i.e. they may plan the verb and the direct object together, before planning the indirect object. These patients’ preference to semantically integrate the dative verb and the theme first before the recipient is consistent with the mapping theory of agrammatic comprehension deficits (O'Grady & Lee, 2005; O'Grady, Yamashita, & Lee, 2005), which proposes that patients have difficulty in processing sentences in which the word order does not match the structure of the corresponding event. For example, active sentences are easier to process than passive sentences because the active structure aligns with how a default transitive event unfolds: i.e., the agent initiates an action on the theme; whereas the passive structure puts the theme in an earlier position before the agent, causing processing difficulties. Similarly, the default dative event structure should be an agent causing a theme to be transferred to a recipient, and corresponds with the surface structure of a PD sentence, but not with a DO sentence. It is therefore predicted by this theory that in both comprehension and production, speakers should prefer a PD structure over a DO structure, and this preference should be much stronger in patients.

There are two lines of evidence from corpus analyses supporting patients’ intuitions that the verb is more closely related to the theme in meaning than to the recipient. These findings reveal that for most dative verbs in English, the theme is an obligatory argument of the verb, but the recipient is often optional. Firstly, most English dative verbs can be used in monotransitive structures with the theme, and the recipient can be omitted. For example, Mukherjee (2005)
researched the International Corpus of English—the British Component, and found that there were 1064 sentences using the verb *give*. Of these sentences 38.0% were DO, 11.6% were PD, and 23.2% were monotransitives with a theme (e.g. *so for instance we can give a very nice account of coarticulation…*), but there was not a single case of monotransitive with a recipient. Similar patterns were also found with three other dative verbs analyzed in Mukherjee (2005), i.e. *show*, *send* and *offer*. Monotransitive sentences using *show* and a theme constituted 36.0% of all sentences using the verb of *show*. Proportions of similar constructions were 24.2% for *send*, and 40% for *offer*. By comparison, only 1.3% of sentences were monotransitives with the verb *show* followed by a recipient. There was only 1 sentence with the same construction for the verb *send*, and no such construction for *offer* in the corpus. Only *tell* was used substantially in monotransitives with only the recipient (16.4%), but there were still quite a few cases of *tell* in monotransitives with only the theme (3.8%, 27 cases). Therefore, it seems that while sometimes the recipient is omitted in a dative sentence, the theme is almost always present in the structure, indicating that the theme is a more important argument than the recipient in the argument structure of most dative verbs.

Secondly, when a dative verb is used in a passive structure with only one argument, normally it should be the theme in the subject position, omitting the *to*-phrase with the recipient and the *by*-phrase with the agent. For example,

(3) A book was sent.

(4) *John was sent.

The intuitive ungrammaticality of Sentence (4) was consistent with the analysis of sentences using the same five dative verbs in Mukherjee (2005) discussed above. Out of all the cases, there
were in total 11 cases like Sentence (4) —all of them using the verb “tell”. By comparison, structures like Sentence (3) were found with all of the five verbs, constituting 0.6% -7.0% of all sentences using the particular verb, again showing that the dative verb is more closely related to the theme than to the recipient.

If the closer semantic relationship between the dative verb and the theme indeed makes PD easier to process than DO, then it should be predicted that speakers should perform even better on PD sentences with more closely related verb-theme collocations than other PD sentences with less closely related verb-theme collocations. Both Experiment 2.1a and 2.1b manipulated the semantic relationship and the collocation frequency between the verb and the theme in dative sentences to examine participants’ performance in the sentence repetition task and the grammaticality judgment task.

**STM and cognitive load during dative sentence processing**

If dative verbs are closely related to themes than recipients, then comprehenders may semantically integrate the verb and the theme before processing the recipient, regardless of surface sentence structure. This processing order would be consistent with the word order in a PD sentence, in which the theme comes right after the verb; but it is inconsistent with the surface structure in DO, in which the verb and the theme are interleaved by a recipient noun. The sentence processing difficulty caused by this inconsistency may be related to the additional STM resources required for producing and understanding a DO sentence.

Many sentence processing models which emphasize on the role of syntactic complexity also attributed complexity effects to higher processing costs, especially STM resources (Gibson,
The role of STM in sentence processing is most apparent in patients with STM deficits. For example, both healthy and patient speakers showed a phrasal scope of advance planning, so that they have slower speech onset latencies for longer vs. shorter initial phrases (Allum & Wheeldon, 2007; Martin, Crowther, Knight, Tamborello II, & Yang, 2010; Martin, Yan, & Schnur, 2014). Patients with semantic STM deficit showed exaggerated speech onset latencies and speech error rates for adjective phrases like the short blonde hair than sentences with post-verbal adjectives like the hair is short and blonde (Martin & Freedman, 2001), for sentences like the dog and the cup move above the table than the dog moves above the cup and the table (Martin, Miller, & Vu, 2004). These findings suggest that before speaking, patients with semantic STM deficit attempt to plan the whole initial subject phrase, and longer initial phrase with more content words caused especially great processing difficulties for these patients. Similarly, these patients with semantic STM deficits also had great difficulties in understanding phrases with pre-nominal adjectives like the rusty old red pail but were much better on sentences with post-nominal adjectives like the pail was rusty, old, and red (Martin & He, 2004). In the phrase condition, patients have to maintain the lexical-semantic information of all three adjectives in their STM until the processing of the noun, which is the head of the phrase. By comparison, to understand the sentence with post-nominal adjectives, patients can semantically integrate the meaning of the noun and the adjectives immediately after processing each adjective, therefore greatly reducing the STM burden.

In light of these theories of STM in sentence processing, for the production of dative sentences, I hypothesize that both at the conceptual and lexical-semantic level of planning, speakers tend to plan the theme right after the verb and before the recipient. According to the
lexical-head principle that Martin and colleagues proposed, after the planning of the subject noun (the agent), speakers should firstly plan the verb. What is critical is the sequence of lexical-semantic planning of the two nouns after the verb. Because of the close semantic relationship between the verb and the theme, in both PD and DO, speakers may plan the theme right after the verb, before the planning of the recipient. This planning sequence is consistent with the syntactic word order in PD. Therefore, speakers can plan PD in a piecemeal fashion, in that the prepositional phrase containing the recipient can be planned at the lexical-semantic level during or after the phonological encoding of the theme. In this way, immediately after the planning of the verb, only one content word (theme) has to be planned in semantic STM. By comparison, in producing DO, although speakers still plan the theme before the recipient, it now has to be produced after the recipient in the sentence string. In other words, the theme is planned earlier than the recipient, but needs to be held in semantic STM and spoken later. Therefore, after the phonological encoding of the verb, both nouns have to be planned and maintained in STM. In this way, producing DO requires more STM resources than PD.

On the side of comprehension, I also hypothesize that because of the inherently close semantic relationship between the verb and the theme, comprehending a dative sentence requires the semantic integration of the verb and the theme into higher-level propositional representations, before the further integration of the recipient. PD is easier to comprehend than DO because it allows the immediate integration of the verb and the theme. By comparison, the intervening recipient in DO delays the immediate semantic integration of the verb and the theme, and requires more STM resources to temporarily hold the recipient until the processing of the theme. Another motivation for listeners to avoid the direct semantic integration of the verb and the recipient in DO even though they are close in syntactic positions is that in English dative
sentences, there is ambiguity regarding whether a noun after a verb is a direct object or indirect object. For example, for a DO sentence like *the doctor sent the patient some medications*, on hearing the string *the doctor sent the patient*, the listener would be undecided whether to parse *the patient* as a recipient, or parse it as a theme, as in a sentence like *the doctor sent the patient to the surgical room*. By comparison, many nouns right after the verb can be immediately parsed as a theme because they are inanimate and thus unlikely as recipients, as in *the doctor sent the medications to the patient*. Therefore, in most DO sentences, where the noun immediately following the verb is animate or refers to an organization (e.g., company, hospital, school), the interpretation of the noun’s thematic role would have to depend on the further information that follows it. By comparison, in most PD sentences, the noun after the verb can be unambiguously parsed as the theme. Therefore, the ambiguity of the thematic role of the noun after the dative verb contributes to the difficulty in processing DO.

As in Study 1, I used the category probe task to measure participants’ semantic STM, and the rhyme probe, digit matching and digit span tasks were used to calculate phonological STM composite scores, and sentence STM was used to measure STM capacities in a sentence context.

**Design and research questions in Experiment 2.1a and 2.1b**

Both tasks in Experiment 2.1a and 2.1b manipulated three factors: structure (DO/PD), type of recipient (full noun/pronoun), and semantic relationship between the verb and the theme (close/far). Sentence examples in the two experiments are shown in Table 2.3. In an attempt to manipulated the ease of integrating semantic information between the verb and the theme, Experiment 2.1a used an index of relatedness derived from latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1988), and Experiment 2.1b further combined the LSA index with an index of collocation frequency between the verb and the theme (the Hyperspace Analogue to
Language frequency Norms, HAL; Lund & Burgess, 1996) in order to obtain a more reliable measure of the ease of semantic integration. The LSA index shows how likely two words appear in the same context of use, and the HAL index shows the frequency of the verb and theme collocation. Combining the two indexes would provide a stronger manipulation of the relationship between the verb and the theme. It is assumed that two nouns that frequently occur together with each other in the same semantic context should have a close semantic relationship and should be easy to be processed together. Below I discuss three research questions to be addressed in Study 2.1 and relevant predictions, in relation to the three potential factors that may affect patient dative sentence processing discussed previously: grammatical knowledge vs. language use, semantic integration of the dative verb with the theme vs. the recipient, and STM.
Table 2.3 Sentence materials used in the two tasks in Exp. 2.1a and 2.1b

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO-Close (DOC)</td>
<td>The senator told the shopper the story.</td>
</tr>
<tr>
<td>DO-Far (DOF)</td>
<td>The senator told the shopper the reason.</td>
</tr>
<tr>
<td>DO-Noun (DON)</td>
<td>The soldier offered the doctor the paints.</td>
</tr>
<tr>
<td>DO-Pronoun (DOP)</td>
<td>The soldier offered him the paints.</td>
</tr>
<tr>
<td>PD-Close (PDC)</td>
<td>The senator told the story to the shopper.</td>
</tr>
<tr>
<td>PD-Far (PDF)</td>
<td>The senator told the reason to the shopper.</td>
</tr>
<tr>
<td>PD-Noun (PDN)</td>
<td>The soldier offered the paints to the doctor.</td>
</tr>
<tr>
<td>PD-Pronoun (PDP)</td>
<td>The soldier offered the paints to him.</td>
</tr>
</tbody>
</table>
Research Question 1: Do speakers who produced fewer DO sentences in the picture description task have consistent difficulties in processing DO in other tasks? Are these difficulties related to syntactic complexity or language experience for dative structures?

PD vs. DO structure was manipulated to determine if we would find worse performance on DO than PD in repetition and grammaticality judgments that would correspond to the findings for picture description in Study 1. Then, participants’ performance on DO sentences with full noun recipients was contrasted to their performance on DO sentences with pronoun recipients to see any potential differences in processing a more frequent DO structure (DO-pronoun) vs. a less frequent DO structure (DO-noun) (Bresnan et al., 2007). If speakers’ difficulties in producing DO sentences are solely due to the syntactic complexity of DO vs. PD (e.g., Beck & Johnson, 2004; Bowers, 2002; Chomsky, 1975), then they should be equally impaired in their performance on all types of DO sentences in both tasks. By contrast, if prior language experience alone determines sentence processing difficulties, then participants’ performance should be closely related to construction frequencies contingent on recipient types: they should have comparable performance on DO vs. PD when the recipients are full NPs, but better processing of DO vs. PD when recipients are pronouns. An approach that incorporates both factors of syntactic complexity and language experience would predict an interaction between the two factors: speakers who had a great preference for PD vs. DO in Study 1.1 may still have more difficulties in processing DO vs. PD with full NP recipients, but their performance should improve dramatically on the more frequent DO construction, i.e., DO sentences with pronoun recipients compared to full NP recipients, leading to reduced or even no difference in processing difficulty between DO and PD.
Research Question 2: Are PD sentences easier to process than DO sentences because semantic relationship is closer between the verb and the theme vs. the recipient?

One factor behind speakers’ choice of dative structure may be the semantic relationship of the verb with the theme vs. the recipient. As discussed before, in general, dative verbs seem to have a closer relationship with the theme, because 1) conceptually an action originates from the agent acts upon the theme and moves it toward the recipient; 2) in English, the theme is usually indispensable in the argument structure of a dative verb while the recipient can often be omitted. Perhaps speakers prefer PD over DO because the surface structure of PD allows the verb to be adjacent to the theme, and allows easy semantic planning/integration between the two semantically closely-related words. In this sense, the preference for PD over DO is related to the semantic relationship between the verb and the objects. Therefore, changing the degree of semantic closeness may change the choice of dative structure. It is predicted that the preference for PD over DO should be greater when the verb-theme relationship is closer than when the verb and the theme are farther away in semantic relatedness. Specifically, when the verb and the theme are closely related, in sentence production, speakers have a stronger tendency to choose the PD structure to put the words together; in sentence comprehension, comprehenders have a stronger tendency to semantically integrate the verb and the theme together before the recipient, causing difficulties in processing DO, which leaves the verb and the theme apart in structure. However, when the verb and the theme do not have a close semantic relationship, speakers may have a smaller tendency to choose a PD to plan the two words together, and may have an increased likelihood to plan the verb and the recipient together, resulting in a DO structure. Comprehenders are also less likely to prioritize the semantic integration of the verb and the theme before the recipient, so in a DO sentence, they may integrate the meaning of content
words according to the order that they perceive these words. Within each structure, one may predict that the PD structure is more sensitive to the effect of semantic relationship between the verb and the theme. But the advantage with a closely-related verb-theme collocation in comprehension may not occur in the DO structure, because the effect may be disrupted by an intervening recipient.

In Experiment 1.1, most pairs of the verb and the theme seemed to be more plausible and frequent collocations than pairs of the verb and the recipient, because the theme nouns were usually common objects (e.g., *apple*, *cup*, *ball*) while the recipient nouns were mostly persons of different professions (e.g., *doctor*, *pirate*, *monk*) and are less likely to be used as recipients of dative verbs in daily conversation than other common animate nouns (e.g., *mom*, *friend*) or pronouns. Indeed, 10/16 pairs of the verb and the theme were higher than counterpart pairs of the verb and the recipient in the LSA index (group mean = 0.14 vs. 0.12). It is possible that speakers with lower production of DO in Experiment 1.1 may be more sensitive to the semantic relationship or collocation frequency between the verb and the objects. Therefore, it is predicted that these participants should show a larger effect of the manipulation of semantic relationship in the current study.

In experimental sentences in Study 2.1, a verb-theme collocation that is high in LSA or collocation frequency indexes is closer in semantic relationship and should be easier for semantic integration. Ideally, it would be good to also the same manipulation for the verb and the recipient, and show that a closer semantic relationship between the verb and theme facilitate the processing of PD while a closer semantic relationship between the verb and the recipient facilitate the processing of DO. This would be stronger evidence supporting the hypothesis that the dynamic semantic relationship between the dative verb and its two objects changes the preference for the
order of semantic integration with one of the objects, and therefore influenced the choice of structure and the processing difficulty between PD and DO. However, there are rarely any high-frequency collocations of dative verb and the recipients; also, their LSA indices are usually very low, making it implausible to manipulate the semantic relationship between the two words. This is actually another piece of evidence showing that the dative verb is generally semantically more closely related to the theme noun than to the recipient noun.

Research Question 3: How is STM related to the processing difficulty of DO sentences?

As was discussed before, the potential differences in semantic relationships between the dative verb and its arguments may induce different STM requirements while processing DO vs. PD. If the dative verb has a closer semantic relationship with the theme than with the recipient in dative constructions, language users, especially those with limited STM capacities might then prefer PD, in which the dative verb and the theme are adjacent to each other in the sentence string. DO would cause processing difficulties because it might require more STM resources than processing PD. It is then predicted that in both the sentence repetition task and the grammaticality judgment task, individual STM capacities should be related to the processing cost of DO vs. PD, i.e., the differences in error rates on the two structures. STM should also correlate with any potential effect of semantic relatedness, i.e., differences between PDF and PDC conditions.

The manipulation of the type of the recipient as either a full noun or a pronoun may also induce effects related to STM. Pronouns are highly frequent and have only one syllable, and therefore are generally shorter and more frequent than full lexical NPs. These factors may make DO sentences with pronoun recipients easier to process, because patients need fewer STM
resources to maintain a pronoun recipient than a full NP recipient when planning or comprehending a DO sentence. However, pronouns have fewer semantic features than full NPs, possibly making them more difficult to maintain/retrieve from semantic STM. The difference in word length may relate to phonological STM but the difference in semantic richness may relate to semantic STM, with opposite effects as indicated above. Therefore, it is predicted that both participants’ semantic and phonological STM capacities may correlate with the effects of pronoun recipients on DO processing.

**Experiment 2.1a Sentence repetition task**

A sentence repetition task tests both sentence comprehension and production. One may argue that sentence repetition does not necessarily require understanding of sentence meaning, because participants can recall the previously presented sentence verbatim from their phonological STM. However, various studies have found that verbatim sentence recall does require sentence comprehension and production that involve sentence processing at various levels (Schweppe, Barth, Ketzer-Noltge, & Rummer, 2015), and sentence recall has been widely used as a measure of language proficiency in educational settings (e.g., Newcomer & Hammill, 1988) and for clinical assessment (Meyers, Volkert, & Diep, 2000). Moreover, most of our patients have a phonological STM span of less than 4 words, making it difficult for them to maintain just the phonological information of a dative sentence (which has four content words) without semantic processing. Therefore, this task does involve other components of sentence processing in patients, including processing at the conceptual, semantic and syntactic levels. Moreover, because the sentence repetition task includes both comprehension and production components of processing
and also has high STM demands, it increased the likelihood of revealing the effects of the manipulated factors on dative sentence processing.

Methods

Participants
Thirteen aphasic patients with varying degrees of sentence processing abilities and STM capacities participated in the sentence repetition task. Twelve of these patients had completed Experiment 1.1, the syntactic priming task with the picture description paradigm. One additional patient, RF, participated in Study 2 but was excluded from Study 1 because her reading deficits made it difficult for her to correctly read the prime sentences. In a picture description task to be reported in Study 2.2, RF produced 60% of dative sentences in the DO structure, leading to the prediction that she should not show any specific difficulty with processing DO vs. PD. Seven control speakers from the Houston area participated in the current experiment. Five of the control speakers were female, and the average age of the control group was 68. Table 2.4 shows proportions of DO production in Study 2.1 and STM capacities of individual patients and the control speaker group.
Table 2.4 Percent DO production in the picture description task in Exp. 1.1 and STM measures

(Patients are ordered by their proportions of DO production in Experiment 1.1)

<table>
<thead>
<tr>
<th>Patients</th>
<th>LC</th>
<th>RI</th>
<th>MLB</th>
<th>RK</th>
<th>FW</th>
<th>WC</th>
<th>PP</th>
<th>MK</th>
<th>GP</th>
<th>KC</th>
<th>DW</th>
<th>RR</th>
<th>RF</th>
<th>Control Mean</th>
<th>Control Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO% in Exp. 1.1*</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
<td>0.21</td>
<td>0.31</td>
<td>0.46</td>
<td>0.65</td>
<td>-</td>
<td>0.13</td>
<td>0.02-0.39</td>
<td></td>
</tr>
<tr>
<td>STM measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category probe span</td>
<td>2.71</td>
<td>3</td>
<td>1.33</td>
<td>2.38</td>
<td>0.71</td>
<td>1.83</td>
<td>3.5</td>
<td>1</td>
<td>4</td>
<td>2.37</td>
<td>2</td>
<td>4.14</td>
<td>3.14</td>
<td>6.2</td>
<td>3.50-7.22</td>
</tr>
<tr>
<td>Phono. Composite</td>
<td>-0.81</td>
<td>-0.62</td>
<td>0.02</td>
<td>-0.73</td>
<td>-1.45</td>
<td>0.75</td>
<td>0.06</td>
<td>-0.12</td>
<td>0.50</td>
<td>0.37</td>
<td>1.48</td>
<td>0.55</td>
<td>0.28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sentence STM task $d'$</td>
<td>-</td>
<td>-</td>
<td>3.20</td>
<td>2.68</td>
<td>1.21</td>
<td>3.09</td>
<td>2.47</td>
<td>2.21</td>
<td>1.99</td>
<td>4.17</td>
<td>2.89</td>
<td>-</td>
<td>1.61</td>
<td>4.18</td>
<td>3.40-4.62</td>
</tr>
</tbody>
</table>

* DO% is the proportion of DO sentences out of all target sentences produced in DO or PD (excluding non-dative responses).
Materials and procedure

As discussed earlier, three factors were manipulated: structure (PD vs. DO), semantic closeness (close vs. far), and recipient type (noun vs. pronoun). Experimental sentences are provided in Appendix G. There were 64 critical sentences, half DO and half PD. Each DO had a corresponding sentence in the PD condition with the same content words but in different word order. Thirty-two sentences were manipulated for semantic closeness and the others were manipulated for the noun type of the recipient (see Table 2.3 for the conditions). Each sentence in the semantically close condition had a counterpart in the semantically far condition and this sentence pair shared the same agent, verb and recipient, but the themes were different to create verb-theme collocations that were high vs. low in the semantic integration index. The average LSA indexes in the close vs. far conditions were 0.47 vs. 0.11. The frequencies of the verb-theme collocation in each sentence pair were controlled, with the average HAL (Lund & Burgess, 1996) log frequencies being 10.63 and 10.39 in the close and far conditions, respectively. Each sentence in the pronoun recipient condition had a counterpart in the full noun recipient condition sharing the same set of agent, verb and theme. There were also 32 fillers, which were non-dative sentences such as the puppy bit him, or the strawberries were delicious.

During the experiment, a female native English speaker read the sentence to the subject, and asked the subject to repeat it. If the subject asked for a repetition of the sentence, the experimenter would repeat the sentence one more time.

Scoring and data analysis

Participants’ best responses in the two repetitions of a sentence were analyzed. A response was scored as correct if the produced sentence used the same content words in the same word order as in the presented sentence. Slight alternations of determiners or inflections were accepted if
grammatical. For example, *the senator was telling the shoppers a story* was scored as a correct repetition of *a senator told the shopper the story*. All other responses were scored as errors, including those that substituted synonyms, e.g. saying *the customer* for *the shopper*.

**Results and discussion**

All control speakers were perfect in repeating all sentences correctly, and therefore their data were not further analyzed. Table 2.5 shows patient repetition performance, together with their proportions of DO production in Experiment 1.1 as a comparison. Comparing DO vs. PD sentences, 7/13 patients showed better repetition of PD sentences than DO sentences. The structure effects (differences in repetition accuracies between PD and DO sentences) in the current experiment had a marginal negative correlation with patients’ proportions of DO production in Experiment 1.1, $r (10) = -.52, p = .081$, showing that patients who produced fewer DO sentences in response to dative pictures also had more difficulties in repeating DO sentences in the current task. Therefore, the current sentence repetition task replicated findings in the picture description task and showed that some patient speakers had consistent difficulties in processing DO vs. PD sentences in different tasks.
Table 2.5 Patients’ percent accuracy rates and effects in repeating sentences in Exp. 2.1a

<table>
<thead>
<tr>
<th></th>
<th>LC</th>
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**Effect of syntactic structure**

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**Effect of construction frequency**

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**Effect of semantic integration**

<p>|                  | 0.00 | 0.00 | 0.13 | 0.00 | 0.25 | 0.63 | 0.00 | 0.13 | 0.13 | 0.00 | -0.25 | 0.13 |
|------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|                 | 0.00 | 0.00 | -0.50 | 0.63 | 0.25 | -0.13 | 0.13 | -0.13 | -0.25 | -0.50 | -0.13 | -0.13 | 0.00 |</p>
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How is this processing difficulty with DO sentence related to other factors that were investigated? Further analysis of the interaction between syntactic structure and pronominality of the recipient suggests that the difficulty with DO sentences were contingent on the type of recipients: while on average patients showed a 10% structural effect in the full NP recipient condition (PDN-DON), there was no structure effect in the pronoun recipient condition (-1%; PDP-DOP). Importantly, percent DO in Experiment 1.1 marginally correlated with the structure effects only in the full NP recipient condition, \( r(10) = -0.50, p = 0.10 \); but not in the pronoun recipient condition, \( r(10) = 0.09 \), which was in the wrong direction (see Figure 2.4 for plots of correlations). As an illustration, among the four patients who produced the fewest DO sentence in the picture description task (LC, RI, MLB, RK; all < 2%), all of them repeated PD better than DO with full NP recipients (PDN-DON>13%), but only two of them still performed better on PD with pronoun recipients. For patients who produced more than 20% of DO sentences in picture description, only one of them (KC) showed similarly better performance with PD than DO with full NP recipients. Looking into the effect of pronoun recipient on each dative structure, pronoun (compared to full NP) recipients improved patients’ performance in DO: 8/13 patients were better in repeating DO sentences with pronoun vs. full NP recipients (DOP-DON), showing a mean of 13% effect (-38%-75%); pronoun recipients also increased performance in PD sentences in 6/13 patients, but the effect was much smaller (mean = 6%, range = -38%-63%)⁸. Thus,

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⁸ The larger effect of pronoun recipients on DO vs. PD can be explained in two ways. One explanation, which is discussed in detail here, is related to the very frequent construction of DO sentences with pronoun recipients. Another explanation is simply that the pronoun recipient is more accessible than full NP recipients, because pronouns are often shorter and more frequent, and language users prefer constructions in which more accessible words is put earlier in the sentence than less accessible words (e.g., Onishi, Murphy, & Bock, 2008). As discussed in the introduction, these two explanations may reflect a general alignment of comprehension and production principles, which shapes distribution frequencies of constructions in language (e.g., Macdonald, 2013). I will return to this issue in Exp. 2.2.
predictions of the language experience account were partially confirmed. Specifically, contrary to a syntactic complexity account which assumes that these patients should have overall deficits in the syntactic knowledge or syntactic processing of DO, but consistent with data showing that DO sentences with pronoun recipients are highly frequent, difficulties with DO vs. PD only existed in the full NP recipient condition (and were marginally related to patients’ difficulties in producing DO in picture description), but not in the pronoun recipient condition. However, contrary to the corpus data showing DO is as frequent as PD (with full NP recipients) or even more frequent than PD (with pronoun recipients), both the picture description task in Experiment 1.1 and the sentence repetition task in the current experiment confirmed that some aphasic patients have consistently more difficulties in processing DO vs. PD. Therefore, these findings are more consistent with a multi-factorial usage-based approach of sentence processing, which predicts that both syntactic complexity, language experience and other processing cost could play a role in sentence processing. Below I will further explore the basis of the structural effect in the full NP recipient condition by exploring its relationship to STM measures and how it interacts with the semantic integration index.
a. Relationship between proportions of DO production in Experiment 1.1 and the structural effects in the full NP recipient condition in Experiment 2.1a

b. Relationship between proportions of DO production in Experiment 1.1 and the structural effects in the pronoun recipient condition in Experiment 2.1a

Figure 2.4 Plots of correlations between percent DO production in Exp. 1.1 and the structural effects in full NP/pronoun recipient conditions in Exp. 2.1a
Appendix H provides correlational data that explores the role of STM in sentence repetition effects and the comparison with patients’ performance in Experiment 1.1. Repeating both DO and PD structures seems to rely more on phonological STM capacities ($r$’s > .75, $p$’s < .01) and sentence STM capacities ($r$’s > .56, $p$’s < .09) than on semantic STM ($r$’s > .25, $p$’s < .16). A multiple regression model revealed that phonological and sentence STM measures altogether accounted for 80% of the variances in the accuracies of DO sentence repetition, while semantic STM did not have any contribution independently of phonological and sentence STM. This may suggest that semantic processing is minimal in the current sentence repetition task.

Critically, the structural effect on dative sentence repetition in the full NP recipient condition (PDN-DON) has a moderate, though nonsignificant correlation with phonological STM, $r$ (11) = -.45, $p$ = .125 (Figure 2.5), i.e., patients with stronger phonological STM capacities have fewer difficulties with repeating DO vs. PD. This was consistent with findings in Study 1.1 that patients’ proportions of DO production also had a relationship with phonological STM ($r$ (10) = .64, $p$ = .024). Semantic or sentence STM did not have a role in the structural effect in dative sentence repetition, with correlations nonsignificant or in the wrong direction, compared to in Exp. 1.1 that semantic STM had a moderate relationship with proportions of DO production, $r$ (10) = .41, $p$ = .186 9 (see Figure 2.3a and b in the introduction for plots of correlations in Exp. 1.1). Together, these findings suggest that producing or repeating DO with full NP recipients indeed requires more STM resources than PD. As I discussed before, additional STM cost with DO may come from the need to temporarily hold the recipient in STM until after semantically

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9 For the eight control speakers from whom we have collected STM measures, however, there was no evidence for a role of phonological or semantic STM in the proportions of DO production in Experiment 1.1, with both correlations in the wrong direction and nonsignificant ($r$’s >.25). It is possible that for speakers with sufficient STM capacities, the choice of structures may be more influenced by other factors (e.g., priming of previously processed structure, accessibility of nouns, etc.) rather than STM.
integrating the verb and the theme during sentence comprehension, or temporarily holding the theme in STM until after producing the recipient during sentence production. The additional STM cost is at the phonological level rather than the semantic level in the current task, possibly because in the current repetition task, repetition of the exact word form was required, and even synonymous words were not accepted. Therefore, maintaining phonological information was more crucial than semantic information. Also, the use of phonological STM as a backup store for the sentence might also of great help to patients when comprehension difficulties occurred, so that they could review parts of the sentence to facilitate comprehension. In the picture description task in Study 1, though, there was some evidence that the semantic STM is also related to the processing difficulty of DO.

![Figure 2.5. Relationship between phonological STM composite scores and the structural effects in the full NP recipient condition in sentence repetition](image)
A closer semantic relationship between the dative verb and the theme did seem to facilitate the processing of PD sentences, improving 7/13 patients’ performance for PD sentences (PDC-PDF > 0), but not for DO sentences (DOC-DOF > 0 for only one patient), indicating that there is a larger tendency to directly integrate the semantics of the verb and the theme in the PD vs. DO structure. More importantly, the syntactic complexity effect of DO sentences only showed up in the condition of a close semantic relationship, PDC-DOC > 0 for 8/13 patients, mean = 14%; but not in the far condition, PDF-DOF > 0 for 3/13 patients, mean = -6%, and this difference in structural effect between close and far conditions was significant, \( t(12) = 2.25, p = .044 \). Moreover, percent DO production in Experiment 1.1 significantly correlated with the syntactic complexity effect in the close condition, \( r (10) = -.61, p = .037 \) but not in the far condition, \( r (10) = -.32, p = .32^{10} \) (see Figure 2.6 for plots of correlations). These findings are consistent with the hypothesis that when the dative verb has a closer semantic relationship with the theme than with the recipient, speakers have a preference for the PD vs. DO structure, while this preference for PD is weakened or may even be reversed when the dative verb and the theme are not closely related semantically. The relation of semantic integration to STM is not clear: the semantic integration effects on DO (DOC-DOF) and on PD (PDC-PDF) were not correlated with any STM measure, \(-.29 < r’s < .11, p’s > .41\), except for the positive correlations between the effect on PD repetition and sentence STM, \( r (8) = .63, p = .050 \). It is hard to explain why speakers with better sentence STM capacities would show a larger semantic integration effect on PD sentences. Perhaps these patients’ stronger STM abilities support a larger planning scope that includes both the verb and the theme in a PD, while patients with smaller STM spans had a word-by-word planning scope which disrupted the semantic integration effect that depends on

\(^{10}\) Comparing the coefficients after applying a Fisher \( r \to z \) transformation, they were not significant, \( Z = .71, p = .47 \), probably because the sample size was very small.
the interrelationship between two words. However, this explanation is contrary to findings showing that phonological STM deficits did not reduce patients’ planning scope during sentence production (Martin & He, 2004; Martin et al., 2004) and that healthy young speakers’ phrasal scope of planning is not affected by semantic/phonological STM loads (Martin et al., 2014).

Figure 2.6 Plots of correlations between percent DO production in Exp. 1.1 and the structural effects in semantically close/far conditions in Exp. 2.1a

a. Relationship between proportions of DO production in Experiment 1.1 and the structural effects in the close semantic relationship condition in Experiment 2.1a

b. Relationship between proportions of DO production in Experiment 1.1 and the structural effects in the far semantic relationship condition in Experiment 2.1a

Figure 2.6 Plots of correlations between percent DO production in Exp. 1.1 and the structural effects in semantically close/far conditions in Exp. 2.1a
Taken together, the sentence repetition experiment found that patients who had produced fewer DO sentences while describing dative pictures also had more difficulties in repeating DO sentences compared to PD sentences, showing a consistent structural effect across tasks. The structural effect was confined to dative sentences with full lexical NP recipients, but did not occur in sentences with pronoun recipients. This is in line with corpus data showing that the DO structure is used much more frequently when the recipient is a pronoun, but does not match the fact that DO is as frequent as PD when the recipient is a full NP. These results can be explained by a usage-based approach that incorporates factors of potential syntactic complexity (e.g., Beck & Johnson, 2004; Bowers, 2002; Chomsky, 1975), processing difficulties, and experience of language use (e.g., Gahl & Menn, 2016). Also, this structural effect occurred when the dative verb has a closer semantic relationship with the theme (and the effect correlated with the structural effect in picture description), but not when the relationship was farther, suggesting that faster semantic integration of the verb with the theme than with the recipient may be another factor that facilitate speakers’ processing of the PD structure. Moreover, the structural effect has STM basis, being related to phonological STM in the current task, and more importantly related to both phonological and semantic STM in the picture description task, indicating that processing DO sentences tax STM resources more than PD sentences.

One thing that cannot be tested in the sentence repetition is whether the processing difficulties of DO vs. PD are related to any possible factor of syntactic complexity, e.g., perhaps DO involves more syntactic movement or abstract syntactic layers (e.g., Beck & Johnson, 2004; Bowers, 2002; Chomsky, 1975). The hypothesis of a general difficulty with the DO structure due to syntactic complexity is inconsistent with the current findings that with pronoun recipients, DO sentences were no more difficult than PD sentences to repeat. However, there are two
limitations with the repetition study design that prevent an easy rejection of a syntactic deficit hypothesis. First, because repetition depends to a large extent on phonological storage, any syntactic complexity effect may have been disguised in the current task. Second, it is possible that the structural effect in the full NP recipient condition indeed had a syntactic complexity basis, but in the pronoun condition, this effect was attenuated by the facilitation of the pronoun recipient on DO processing, and the weak effect may not be easily detected in a sentence repetition task that depends more heavily on STM than on syntactic processing. Therefore, I conducted a grammaticality judgment task in Experiment 2.1b to more directly test if grammatical processing of DO is more difficult than PD.

**Experiment 2.1b Grammaticality judgement task**

A grammaticality judgment task (GJT) was used to assess participants’ syntactic knowledge and syntactic processing of the of dative structures. If low proportions of DO production in some speakers in Experiment 1.1 were due to syntactic complexity, possibly because DO involves additional syntactic movement (e.g., Chomsky, 1975) or one more layer of abstract syntactic projection (Beck & Johnson, 2004; Bowers, 2002), then one should expect these participants to show worse performance on the DO structure vs. the PD structure in a task that focuses on grammatical aspects of processing. Specifically, participants weaker in the syntax of DO should be more accurate in accepting grammatical PD than DO sentences and more accurate in rejecting ungrammatical PD than DO sentences. Furthermore, a syntactic complexity hypothesis may predict that pronoun recipients and semantic integration between the dative verb and objects may affect the size of the structural effect, but should not eliminate it. STM capacities at the sentence level are more likely than semantic or phonological STM to have a role in this structural effect.
Methods

Participants

Twelve aphasic patients participated in the grammaticality judgment task. Five control speakers from the Houston area participated in the current experiment, with three of them having participated in Experiment 1.1 and all of them having completed Experiment 2.1a. Four of the control speakers were female, and the average age of the control group was 72.

Materials and procedure

Similar as the sentence repetition task, the GJT manipulated three factors: structure (DO/PD), semantic closeness (close/far) and type of recipient (full noun/pronoun). The eight conditions and examples were shown in Table 2.3 in Experiment 2.1a and the experimental stimuli were provided in Appendix I. One set of sentences were manipulated by counterbalanced crossing of the factors of structure and semantic closeness. Another set of sentences were created by crossing structure and recipient type. There were 64 sentences manipulated for structure and semantic closeness, with 16 sentences in each of the four conditions. Pairs of the verb and the theme in the semantically close condition were both higher in LSA (0.39 vs. 0.10 on average) and in log HAL collocation frequency (5.49 vs. 2.50 on average) than in the far condition. But the frequencies of the theme nouns were matched between the two conditions (10.48 vs. 10.63 on average). There were 256 sentences manipulated for structure and recipient type, with 64 sentences in each condition. Half of sentences in each condition were grammatical and the other half were ungrammatical. Each ungrammatical sentence had only one error. The error could be of one of the three types:

a) An auxiliary error: *The senator has/will telling the shopper the story; or *The senator are telling the shopper the story;
b) A case error: *The senator told she the story;

c) A mapping error: *The senator told the story the shopper; *The senator told the shopper to the story.

These error types were designed to represent a variety of different possible grammatical errors that could occur in dative sentences. Type (c) errors were created to require participants to utilize their knowledge of information structure constraints in dative sentences in the current task instead of focusing on detecting local grammatical errors (both Type (a) and Type (b) errors are inflection errors). Information structure constraints require that in a PD, the direct object and the prepositional/indirect object should be mapped to thematic roles of theme and recipient, respectively. By comparison, in a DO, the two object after the verb should be mapped to recipient and theme, respectively. However, when a participant failed to detect a mapping error, it was not clear whether the sentence was parsed as a PD or DO structure. For example, *The senator told the story the shopper could be corrected as The senator told the story to the shopper by inserting a preposition, or as The senator told the shopper the story by changing the word order of the two objects. Therefore, data on Type (c) was analyzed separately from other critical trials. The experiment also had 288 fillers, including 72 intransitives, 168 transitives in active or passive forms, and 48 donate-type sentences (e.g. the gentleman donated some cash to the church or *the gentleman donated the church some cash).

Participants were asked to judge “if the sentence they heard is a good sentence or not”, instead of a question like “is this a grammatical sentence”. This was to prevent participants from the influence of their idiosyncratic knowledge of grammar, and to avoid possible misunderstanding of the term “grammar”. All control participants completed the task in one session in about 1.5 hours. To prevent fatigue with patients, the materials were divided into three
lists and each patient completed only one list during a visit to the lab. The three lists were about the same in the number of sentences in each condition. Each list took patients about 40 minutes to complete. The presentation of sentence materials was controlled by Psyscope X B51 (Bonatti, 2010; Cohen, MacWhinney, Flatt, & Provost, 1993). The sentences were read and recorded by a female native speaker of English. During the experiment, the computer presented to the subject each sentence auditorially, before printing on the screen “Is this a good sentence?”. After the subject pressed one of the buttons on the response box to make the judgment, the experimenter pressed the spacebar to start the next trial. The computer recorded the judgments participants made and the associated RTs. Before starting each session, participants were given instructions and then did 16 practice trials. The practice trials included different experimental and filler sentence structures and different types of grammatical errors that would occur in the experiment. Feedback was provided at the end of each practice trial but not during the experiment.

**Scoring and data analysis**

In the GJT, responses were scored as correct if they made the right judgment of sentence grammaticality. Accuracy rates were calculated by combining grammatical and ungrammatical sentences. Similar to the scoring of the sentence STM task described in Study 1, participants’ $d'$ scores were calculated for each condition.

**Results and discussion**

Control speakers performed near ceiling, with a mean accuracy of 98% across conditions and all speakers scored over 92% correct in all conditions. I therefore focused on the patient data in this study. Table 2.6 shows the accuracy data of patients in each condition. Patients showed great variation in performance on this task, ranging from GP who performed at the level of controls, to FW, MK and KC, who performed very poorly. Table 2.7 reports $d'$ scores in each condition and
effects of structure, recipient type and semantic integration. Appendix J reports correlations of
effects in the current task with STM measures and percent DO in Experiment 1.1.

Performance on both the PD and DO structures was significantly correlated with category
probe spans ($r > .69, ps < .02$), but not with phonological composite scores ($r < .34, ps > .28$)
or sentence STM $d'$ scores ($-.05 < r < .01$). It seems that substantial degrees of semantic
processing were involved in judging sentences. Possibly, patients used their semantic STM to
maintain the meaning of the words during the sentence presentation, and this helped them to
recall the sentence to reprocess it and make judgments at the end of the trial. It was surprising
that sentence STM $d'$ scores had no relationship to performance in the current task. Perhaps in
the current task, the abilities to detect grammatical errors—many of which were inflection errors—
did not draw on the capacities in the sentence STM task, which were employed to retain lexical
or structural information in sentence context.
Table 2.6 Individual patients’ percent accuracy rates in each condition in Exp. 2.1b

<table>
<thead>
<tr>
<th></th>
<th>LC</th>
<th>RI</th>
<th>MLB</th>
<th>RK</th>
<th>FW</th>
<th>WC</th>
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<td></td>
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<tr>
<td>DO-close</td>
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<td>0.67</td>
<td>0.67</td>
<td>0.83</td>
<td>0.67</td>
<td>0.75</td>
<td>0.75</td>
<td>0.67</td>
<td>0.92</td>
<td>0.50</td>
<td>0.75</td>
<td>0.33</td>
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<td>0.67</td>
<td>0.58</td>
<td>0.75</td>
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<td>0.80</td>
<td>0.73</td>
<td>0.93</td>
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<td>0.93</td>
<td>0.75</td>
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<td>0.79</td>
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<td>0.83</td>
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Table 2.7 Individual patients’ d’ scores in each condition and effects in Exp. 2.1b

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<td><strong>d’ score in each condition</strong></td>
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<td>0.41</td>
<td>0.48</td>
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</table>

**Effect of construction frequency**

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<th></th>
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<th>PDP-DOP</th>
<th>DOP-DON</th>
<th>PDP-PDN</th>
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<td>-0.30</td>
<td>-0.64</td>
<td>0.00</td>
<td>-0.21</td>
<td>-1.00</td>
<td>-0.90</td>
<td>0.77</td>
<td>0.52</td>
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<td>-0.54</td>
<td>0.01</td>
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<td>-0.30</td>
<td>0.71</td>
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<tr>
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<td>1.47</td>
<td>0.60</td>
<td>-0.05</td>
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</table>

**Effect of semantic integration**

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<tr>
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<th>PDC-DOC</th>
<th>PDF-DOF</th>
<th>PDC-PDF</th>
<th>DOC-DOF</th>
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<td>-0.67</td>
<td>1.15</td>
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<td>-0.09</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>-0.38</td>
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</tr>
<tr>
<td></td>
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<td>-1.06</td>
<td>-0.48</td>
<td>1.35</td>
<td>0.48</td>
<td>0.00</td>
<td>-0.38</td>
<td>0.99</td>
<td>-0.38</td>
</tr>
</tbody>
</table>

|        | 0.67    | -1.06   | -0.48   | 1.35    | 0.48  | 0.00  | -0.38 | 0.99  | -0.38 | -1.89 |

|        |         |         |         |         | 0.00  |      |      |      |      |      |
|        |         |         |         |         | -1.35 |      |      |      |      |      |

|        |         |         |         |         | 1.35  |      |      |      |      |      |
Comparing between PD and DO, although 9/12 patients did perform better on PD sentence than DO sentences, the effects were general very small (group mean = 1.42 vs. 1.21), and the pattern of patient performance was inconsistent with that in Experiment 1.1. For example, among the four patients who produced fewer than 2% DO sentence in the picture description task, two of them scored slightly better on PD than DO (LC and RK), and the other two scored slightly better on DO than PD (RI, MLB). The correlation between the structural effect in the GJT (PD-DO) and percent DO in the picture description task was nonsignificant and in the wrong direction, $r(9) = .40, p = .22$. Similarly, in the pronoun recipient condition or in the full NP recipient condition, grammaticality judgments were not consistently more difficult for DO vs. PD for patients who were reluctant to produce DO sentences, and the structural differences across patients were not related to percent DO in production ($r_s < .34$ and in the wrong direction). Therefore, although there was some weak evidence that DO is slightly more complex than PD in syntax, the choice of dative structure in sentence production was not related to this difference in syntactic complexity.

In terms of the effect of pronoun vs. lexical recipients, patients as a group did slightly better with pronoun recipients for both structures (DOP-DON = .44, PDP-PDN = .82 on average), and this improvement of pronoun recipients on DO processing was equal for the four patients with lowest percent DO in sentence production (.57) vs. the four patients with highest percent DO production (.70). Therefore, there was no evidence that pronoun recipients helped syntactic processing of DO sentences in patients with limited DO production. Similarly, the semantic relationship between the verb and the theme did not aid grammatical judgments of PD sentences, with only 4/12 patients showing a positive effect (PDC-PDF > 0), and two of these four patients producing the highest proportions of DO in the picture description task.
One might argue that because grammatical errors in dative sentences in the current study were all inflection errors, they might not have tapped structural processing differences between PD and DO. In other words, even if patients were weaker in the syntax of DO vs. PD, this weakness might be irrelevant of their ability to detect inflection errors in dative sentences, resulting in the null structural effect in the current study. In this sense, data on Type (c) mapping errors, which involved errors on the structural level, may be more relevant to assess patients’ syntactic processing abilities. Another possible explanation of the null result could be that patients who had weaker syntactic representation of the DO structure and thus had difficulties in processing DO sentences might reject DO trials even when they were grammatical. This would result in worse performance on grammatical DO vs. PD sentences, as predicted, but unpredictively better performance on ungrammatical DO vs. PD sentences. A direct test of both explanations would be to look into patients’ performance just on grammatical trials. If they indeed had weaker syntactic knowledge of DO, then they should be impaired in accepting grammatical DO sentences. I therefore analyzed accuracies of patients on grammatical trials and on mapping error trials separately. Table 2.8 shows patients’ accuracies on grammatical trials and on Type (c) mapping errors trials, broken down into two categories: trials with pronoun recipients, and trials with lexical full NP recipients. Note that trials with lexical full NP recipients include all conditions except the pronoun condition, so that, for example, accuracy on DOL was the mean accuracy of DON, DOC and DOF. For the convenience of discussion, I provide the examples for Type (c) mapping errors in each construction below. Trials were labeled according to its surface syntactic structure regardless of its information structure, so that a sentence with two objects were treated as a DO structure and a sentence with a preposition was treated as a PD structure.
DOP: *The senator told the story him;

PDP: *The senator told him to the story;

DOL: *The senator told the story the shopper;

PDL: *The senator told the shopper to the story.

As shown in Table 2.8, on grammatical trials, there was some evidence that PD sentences were easier to judge for full noun recipients (4% advantage) and DO recipients were easier to judge for pronouns (3% disadvantage for PD), with the difference in effects between the two types of recipients being 7% on average. On ungrammatical mapping error trials, there was a similar difference in performance on PD than DO trials (a difference of 15% with pronoun recipients and 8% with lexical NP recipients, for a 7% difference in the effect, which again indicated a pronoun effect on DO processing), showing a tendency to wrongly accept PD trials like *The senator told the shopper to the story. This can be taken as evidence showing that patients had a preference for the PD structure with a preposition, which serves as a grammatical cue facilitates parsing of the sentence structure. Perhaps patients might have focused more on judging the sentence structure rather than the semantic plausibility of the sentences, and therefore more likely to accept *The senator told the shopper to the story, while rejecting *The senator told the story the shopper because there was no preposition in the DO structure to help distinguish grammatical functions of the two objects. Admittedly, this is very speculative and more research is needed to understand patients’ processing of these ungrammatical dative sentences with structural errors. Also, the tendency to accept PD trials regardless of grammaticality did not relate to percent DO production in Exp. 1.1. I took the difference between the structural effects in grammatical and ungrammatical trials with pronoun recipients
(grammatical (PDP-DOP)- ungrammatical (PDP-DOP)) and with lexical full NP recipient
(grammatical (PDL-DOL)- ungrammatical (PDL-DOL)), and correlated the effects with percent
DO production, but found no relationship \(-0.10 < r_s < 0.02, p_s > 0.79\). These results provide
additional evidence that grammatical processing was not a factor influencing the choice of
structure in dative sentence production. They did, however, provide further evidence that the
presence of pronouns conditions facilitated the processing of DO relative to PD structures.
Table 2.8 Accuracy on grammatical trials and trials with mapping errors in Exp. 2.1b

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<td>0.88</td>
<td>0.84</td>
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<td>0.00</td>
<td>-0.50</td>
<td>0.13</td>
<td>-0.13</td>
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<td>-0.13</td>
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<td>-0.31</td>
<td>-0.13</td>
<td>0.32</td>
<td>-0.19</td>
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</tr>
</tbody>
</table>
Grammaticality judgment tasks have been widely used as a methodology to probe into grammatical representations and syntactic processing in speakers, but it was not clear how much semantic processing is involved in such tasks. In the current experiment, it was shown that performance in the current task was highly correlated with lexical-semantic STM capacities, indicating that patients at least tried to process meaning on a lexical level. Similarly, Wilson and Saygin (2004) also showed that aphasic patients in their study showed performance in a GJT is related to general sentence comprehension measures. Nevertheless, a more direct test of sentence comprehension would be helpful to better understand input processing of dative sentences. Therefore, a sentence anomaly task was designed for Experiment 2.1c. Also, the task introduced a new set of sentence stimuli, namely “provide-with” sentences to explore the function of the preposition “to” in PD sentences.

**Experiment 2.1c Sentence anomaly judgement task**

As was discussed in the introduction, a possible source of patients’ difficulty in processing DO sentences may be that there is no salient grammatical marker in the DO structure to determine grammatical functions or thematic roles. Sequences of NPs without any morphemes or prepositions to marked for their grammatical functions are difficult to comprehend (Frazier & Fodor, 1978). The direct object at the end of a DO lacks an explicit grammatical marker, and therefore has to rely on the nonadjacent verb to assign its grammatical function, making the parsing of a DO difficult (Stowell, 1981). For example, while in a PD sentence like *The sailor sent a book to the monk*, the preposition “to” always indicate that the noun following it is an indirect object and a recipient, in a DO sentence like *the sailor sent the monk a book*, the parsing
of the “monk” right after the verb is temporarily ambiguous, because it could either be an indirect object and a recipient in the above example, or a theme in the sailor sent the monk to the temple. Therefore, comprehenders have to continue processing the second object in a DO sentence and then rely on the word order to decide the grammatical functions/thematic roles of the two nouns after the verb—the first noun should be an indirect object and a recipient, and the second noun should be a direct object and a theme. One possibility is that some patients may have deficits in positional processing, so that they cannot use word order information to parse a sentence to assign grammatical roles to nouns. Instead, they have to use function morphemes (e.g. “to” in a PD sentence and “-ed” or “by” in a passive sentence) to perform grammatical decoding.

Whether aphasic patients can have selective impairments in positional processing is controversial. Do they have difficulties in making use of word order information during sentence parsing or producing words in correct sentence positions? Aphasic patients often have poor performance on “reversible sentence” like the mouse is chasing the cat, in which either noun can play the thematic role of an agent or a theme. They may either incorrectly match the sentence to a picture which depicts a cat chasing a mouse in a sentence comprehension task, or incorrectly producing a sentence like the cat is chasing the mouse to describe a picture of a mouse chasing a cat (Martin & Blossom-Stach, 1986; Saffran, Berndt, & Schwartz, 1980). Patients typically perform much better on non-reversible sentences like the man ate the apple, in which other linguistics cues (in this case, the contrast in animacy) helped them to determine thematic roles. Some researchers argued that these patients have word order deficits, in that they have difficulties in parsing a sentence based on its word order to determine grammatical roles or thematic roles. In production, they may also have difficulty in mapping the grammatical and thematic roles to the correct position in the sentence frame (Saffran, Schwartz, & Marin, 1980).
However, some other researchers believe that many patients should be able to assign grammatical roles to nouns based on word order, because they do well in judging grammaticality of reversible sentences. Their deficits are argued to be in mapping grammatical roles to functional roles, (Linebarger, 1993; Linebarger, Schwartz, & Saffran, 1983). From this view, patients can determine that the sentence initial noun “the mouse” is a subject, but have trouble understanding the subject as an agent. Some cross-linguistic evidence from various patients speaking English, Italian or German even argued that it is very rare for aphasic patients to have true word order deficits, although they do have a tendency to reduce syntactic complexity, and overuse canonical word order during sentence production (Bates et al., 1988).

Even if patients do not have word order deficits, they may still be impaired at processing DO sentences because PD is more aligned with the canonical English word order: the first part of “subject-verb-direct object” has the same structure as simple active sentences, and would be easy to process. The last part of “to-indirect object” at the end of the sentences is not canonical, but the explicit function word of “to” helps patients in processing. For DO sentences (e.g., *the sailor sent the monk the book*), which have non-canonical word orders very different from simple active sentences, patients may incorrectly parse the first noun following the verb as a direct object/theme, which would result in confusion once they encounter the word “a book” and realize that the original interpretation of “the monk” is implausible (Caplan & Futter, 1986). The lack of any explicit function word make the parsing of the last word (“a book”) less efficient, contributing to the comprehension confusions.

Alternative explanations of the difficulty with DO without assuming a facilitating role of the preposition “to” include the mapping theory of aphasic comprehension deficits (O'Grady & Lee, 2005; O'Grady et al., 2005). This theory did not assume any difficulty in mapping grammatical
functions to thematic roles for individual words, but argues that to integrate the meaning of individual words into a coherent sentence, a comprehender would follow a default dative event structure of “agent-verb-theme-recipient”, which aligns with the surface structure of a PD but not DO. Also, the hypothesis that a closer semantic relationship between the verb and the theme favors a PD structure over a DO structure was also partially supported by data in Experiment 2.1a.

Patients’ performance on the “provide-with” structure would be useful to determine if an explicit function word is indeed helpful in grammatical parsing. A sentence like *the nurse provide the patient with a pill* is similar to a DO sentence both in the grammatical structure (subject-verb-indirect object-direct object) and in the information structure (agent-verb-recipient-theme), but different in an explicit function word of “with”. If patient performance on provide-with sentences is at the same level as that on PD sentences, which is much better than on DO sentences, then we can conclude that explicit function words are vital for processing of sentence with non-canonical word order. However, if provide-with sentences are as difficult as DO sentences for patients, then the difficulty may come from the non-canonical word order that is different from the “subject-verb-direct object” structure, or from a non-canonical information structure that is not aligned with “agent-verb-theme-recipient”, or from the tendency to put the verb and the theme (vs. the recipient) together in the surface sentence structure to allow easy semantic integration.

**Methods**

**Participants**

Eight aphasic patients participated in the sentence anomaly judgment task. Nine control speakers from the Houston area participated in the current experiment, with five of them having
participated in Experiment 1.1. Seven of the control speakers were female, and the average age of the control group was 75.

**Materials and procedure**

A sentence anomaly task was used. Participants heard each sentence and judged if the sentence made sense. Each participant came to the lab twice to finish two lists of materials. List A consisted of 24 DO sentences, 48 PD sentences, 24 provide-with sentence, and 96 filler sentences. All experimental sentences used full lexical NPs and no pronouns. Half of the sentences were plausible and the other half implausible. Implausible experimental sentences swapped the syntactic positions of the theme and the recipient in the sentence. Examples of implausible sentences are:

1) implausible DO: *The sailor gave the fork the student;*

2) implausible PD: *The sailor gave the student to the fork;*

3) implausible provide-with sentence: *The teacher provided the homework with students.*

Implausible filler trials had nonsensical verb-noun collocations or scenarios, e.g., *the man bit the dog,* or *the mother swept the ocean.* One might argue that for Sentence 1, a participant may consider it as a grammatical error caused by a missing preposition in a PD sentence, as in *the sailor gave the fork to the student.* To prevent such considerations, participants were instructed that incorrect sentences did not have grammatical errors, but were implausible in meaning, therefore, they should focus on the meaning of the sentence during the experiment. Participants were also given 12 practice trials with 6 implausible sentences and were given feedback to their judgement during the practice.
The verbs in the provide-with sentences were alternating verbs that could be used both in a provide-with structure (the nurse provided the patient with a pill) and in a prepositional structure (the nurse provided a pill to the patient). These words were selected from the following set: credit, entrust, furnish, issue, leave, present, provide, serve, supply, and trust (Levin, 1993). Half of PD sentences had provide-type verbs and were paired to provide-with sentence. The other half of PD sentence had give-type verbs and were paired to DO sentences. List B has the same stimuli except that all provide-with sentence in this list were in the PD structure in List A, and all provide-with sentences in List A were in the PD structure in List B. The other half of PD sentences in List B with give-type verbs were in the DO structure in List A, and all DO sentences in List B were in the PD structure in List A. This would allow the comparison of sentences with the same message, but with different structures (PD vs. DO; PD vs. provide-with). Appendix K provided experimental stimuli used in the current task. Patients completed each list in about 40 minutes and controls generally completed each list within 30 minutes.

Scoring and data analysis

Participant responses were scored as correct if they made the right judgment of sentence anomaly. Accuracy rates were calculated for each condition. Similar as the scoring of the sentence STM task and the GJT, participants’ $d'$ scores were calculated in each condition.

Results and discussion

Control speakers again performed near ceiling, with an average accuracy rate of 97% across conditions and all speakers scored over 88% correct in all conditions. Therefore, accuracy data of control speakers was not further analyzed. Instead, RT data were analyzed to explore differences in relative difficulties in judging plausibility of sentences in different conditions. Responses that were longer than 10 seconds were eliminated and then standard deviations were calculated.
Outliers greater than 2.5 standard deviations away from the mean of a participant were also deleted. Table 2.9 shows average RTs in each condition of controls, and accuracy rates and $d'$ scores of patients. Differences between sentence types were calculated with a three-way comparison of DO, PD and provide-with sentences.
Table 2.9 Individual patients’ percent accuracy rates and $d'$ scores in each condition and mean control RTs in Exp. 2.1c

(Y = plausible condition, N = implausible condition, WITH = “provide-with” type sentences)

<table>
<thead>
<tr>
<th>Patients</th>
<th>MLB</th>
<th>WC</th>
<th>PP</th>
<th>MK</th>
<th>GP</th>
<th>KC</th>
<th>DW</th>
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<tr>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>Y</td>
<td>-0.04</td>
<td>-0.25</td>
<td>0.13</td>
<td>0.04</td>
<td>0.17</td>
<td>0.17</td>
<td>0.00</td>
<td>0.25</td>
<td>-198</td>
</tr>
<tr>
<td>N</td>
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<td>-0.08</td>
<td>-0.13</td>
<td>-0.29</td>
<td>-0.13</td>
<td>-0.50</td>
<td>-0.54</td>
<td>689</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.00</td>
<td>-0.17</td>
<td>0.00</td>
<td>-0.13</td>
<td>-0.06</td>
<td>0.02</td>
<td>-0.25</td>
<td>-0.15</td>
<td>251</td>
</tr>
<tr>
<td>$d'$</td>
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<td>-1.58</td>
<td>0.12</td>
<td>-0.60</td>
<td>-0.78</td>
<td>0.69</td>
<td>-2.04</td>
<td>-0.78</td>
<td></td>
</tr>
</tbody>
</table>
Comparing between PD and DO sentences, control speakers were quicker in judging PD sentences than DO sentences, showing a 99ms advantage on average, which was significant in the by-item analysis \( t(47) = 2.15, p = .037 \) though not by-subject analysis \( t(8) = 1.61, p = .15 \). Unexpectedly, 5/8 patients performed better on DO trials than PD trials, and for four of the patients with lowest percent DO production in Experiment 1.1, three of them scored better on DO vs. PD. Consequently, the correlation between the proportion DO sentences from Exp. 1.1 and the accuracy difference between PD and DO in this experiment was in the wrong direction and nonsignificant \( r(5) = .37, p = .42 \). A closer examination of the data showed that implausible trials were especially difficult for patients to judge relative to plausible trials (similar to the case in Exp. 2.1b that ungrammatical trials were much more difficult to judge than grammatical trials). Importantly, similar to the grammaticality judgement task, implausible PDs (e.g., The sailor gave the student to the fork) were somewhat more difficult to judge than implausible DO sentences (e.g., The sailor gave the fork the student), with the average accuracy among patients as 68% vs. 74% for implausible PD vs. DO. For example, the two patients (WC and MK) who showed the largest overall advantage of DO vs. PD scored at a very low level on implausible vs. plausible PD trials (21% vs. 83% and 46% vs. 71%). They also showed worse performance on implausible vs. plausible DO trials, but on a smaller scale (46% vs. 100% and 75% vs. 83%). Comparatively, although control speakers had a large RT advantage with PD vs. DO on plausible trials (252ms), there was no structural effect on implausible trials, indicating that implausible PD trials were also relatively more difficult for controls to judge.

Although we had hypothesized that the presence of the grammatical marker “to” might aid production and comprehension of thematic roles in PD sentences, one might make the case that the opposite might be true in comprehension – that is, that patients might have difficulty
detecting the unstressed “to” in the anomalous PD sentences. A high degree of acoustic sensitivity was required to perform correctly on these trials. Patients like WC and MK might have difficulties in perceiving “to”, and therefore incorrectly accepted the implausible PD trial as a DO sentence. Control speakers might also spend longer time on implausible PD sentences to verify if a “to” was spoken in the sentence. In line with this hypothesis, Wilson and Saygin (2004) speculated that one important factor affecting aphasic patients’ performance on the GJT in their study was difficulties in perceiving redundant unstressed function words like “that” in ungrammatical sentences like *Which woman did John think that saw Tony?*. However, the hypothesis that poor perception of “to” led to incorrect acceptance of implausible PD sentences was not supported by patients’ speech perception measures collected in background testing. In a consonant discrimination task in which patients judged if a pair of auditorily presented words (which could differ in a consonant) were identical, all patients scored above 90% accuracy (except for MLB at 85%). Also, the hypothesis that patients had difficulty perceiving “to” is not consistent with data in Exp. 2.1a, in which patients were better able to repeat PD vs. DO sentences, and there was hardly any case in which patients dropped the “to” and repeated a PD sentence in a DO structure. A more possible explanation of the tendency to incorrectly accept implausible PD sentences is a hypothesis similar to that proposed in Exp. 2.1b to explain a similar tendency in patients to accept ungrammatical PD sentences. The assumption is that patients have a general preference for the PD structure over the DO structure because the explicit grammatical cue of “to” in PD helps comprehenders to determine grammatical functions and parse the sentence structure. Again, in the current task, patients showed a similar tendency to accept implausible PD sentences based on their preference for the PD sentence structure. One might question why wouldn’t patients detect the semantic implausibility when accepting
implausible PD sentences. One possibility is that patients were trying to make sense out of implausible sentences based on their understanding of the individual words and a shallow processing of the sentence structure. This possibility is consistent with the good-enough theory of language processing which argues that sentence parsing in comprehenders is often shallow, and is facilitated by world knowledge in long-term memory, resulting in imprecise interpretations of the sentence (Karimi & Ferreira, 2016). For example, even healthy speakers sometimes failed to realize that the dog was bitten by a man was implausible-- concepts based on good understanding of the content words were organized under the guidance of the knowledge of the most plausible event, and this misinterpretation was only possible because it failed to be corrected by the imprecise parsing of the passive structure (Ferreira, 2003a).

Impaired judgment on implausible vs. plausible sentences also appeared in the provide-with sentences. Between implausible vs. plausible provide-with sentence trials, controls speakers took 376ms more to judge implausible provide-with sentences, and all patients scored more than 21% worse on implausible provide-with trials. Comparing between PD and provide-with sentences, in control speakers, while plausible PD and provide-with took comparable time to judge, implausible provide-with trials cost 439ms more to reject than implausible PD trials. Similarly, all but one patient scored lower on implausible provide-with vs. PD sentences but no patient showed the same pattern on plausible trials. 6/8 vs. 3/8 patients scored at or below the chance level on implausible provide-with sentences vs. implausible PD sentences. These results suggested that implausible provide-with sentences (e.g., The teacher provided the homework with the students) were even more difficult to reject than implausible PD sentences. Indeed, some patients and control speakers mentioned that they often considered different interpretations of a provide-with sentence in the implausible condition. For example, The teacher provided the
homework with the students could potentially be interpreted as The teacher provided the homework that the students possessed or The teacher, together with the students, provided the homework. The preposition “with” was intended to be used as a marker of the indirect object/theme, but was misinterpreted as a possessive case maker or an adverbial phrase indicator in the alternative interpretations. The different potential grammatical functions of “with” here were similar to the ambiguous interpretations in the well known garden-path sentence type used in many psycholinguistic studies: the man saw the woman with the binocular, in which the prepositional phrase could be used to modify the verb “saw” or the NP “the woman”, resulting in different sentence meanings. After a pilot study for the current task, a substantial amount of work has been made to modify sentence stimuli to avoid these types of alternative interpretations; however it did not seem to have completely prevented participants from considering these interpretations, even though control speakers did perform near ceiling in accuracy.

Setting aside the data on implausible PD and provide-with sentences, RTs of control speakers just on plausible sentences were more consistent with predictions, but accuracy rates of patients on plausible sentences were hard to interpret. Specifically, controls were 252ms faster on PD vs. DO, showing a structural effect found in patients in Experiment 1.1 and 2.1a. Their RTs were similar on PD vs. provide-with sentences (4ms different), but provide-with sentences were 198ms faster to judge than DO sentences, showing that the prepositions facilitated the parsing of the sentence structure. As for patients, 4/8 patients (the four patients with lowest percent DO production) scored better on plausible DO vs. PD sentences, thus the data pattern was not consistent with the choice of structure in dative production. 5/8 patients were better on plausible provide-with sentences than PD sentences, an unexpected result given provide-with sentences have a similar information structure as DO sentences, and therefore not supporting the
hypothesis that this information structure is more difficult because it does not align with the default dative event structure. Comparing between plausible provide-with sentences and DO sentences, the only two patients (MLB, WC) who were better at DO sentences had the lowest percent DO production, again contrary to predictions. The unexpectedly better performance on DO than PD and provide-with sentence even on plausible trials among patients who were reluctant to produce DO may be in part resulted from the confusion with the functions of prepositions in PD and provide-with sentences. While “to” in PD marks a following noun as an indirect object/recipient, “with” in provide-with sentences marks a following noun as a theme. Frequently encountering these two types of prepositional phrases in a short period may have affected patients’ differential parsing of the two sentence structures.

A better future design comparing among PD, DO and provide-with sentences should have PD and provide-with sentences in different lists, rather than mixing them in the same list/block. Also, given the multiple alternative interpretations of implausible PD and provide-with sentences, it is recommended that only plausible and grammatical sentences should be used as experimental stimuli. Possible paradigms may include a self-paced reading/listening task, which examines participants’ speed in understanding sentences, or an act-out task, which asks participants to reconstruct events described in sentences with objects.

In sum, control speakers were faster in semantic processing of plausible PD and provide-with sentences than DO sentences, indicating that having a preposition as a salient case marker helps parsing of dative sentences in correct sentences. This could be one reason that when full lexical NPs are used in dative sentences, PD is an easier structure to process than DO. In implausible sentences, however, control speakers did not show any difference between judging PD vs. DO sentences, and patients showed a tendency to incorrectly accept implausible
sentences. Possibly, a general preference for a dative syntactic structure with a preposition serving as an explicit grammatical marker, together with a “good-enough” manner of shallow sentence processing (Ferreira, 2003a; Karimi & Ferreira, 2016) resulted in this incorrect acceptance of implausible PD sentences. Also, possibly because of the unexpected alternative interpretation of implausible prepositional phrases, patients’ performance on provide-with sentences was not readily interpretable and further studies are needed to investigate this issue. Nevertheless, no evidence was found in Exp. 2.1b and 2.1c that patients’ difficulties in producing DO in Study 1.1 were related to any similar difficulty in comprehending DO sentences. Apart from possible confounding factors or experimental design problems discussed in Exp. 2.1b and 2.1c that might disguise any real difficulty in parsing DO sentences, it is certainly possible that the null effect reflects real differences in input vs. output processing of the dative structures. I will return to this in the general discussion. For example, producing a dative sentence starts with a conceptual event structure, and the order of objects in this event structure may have a strong influence on the word order in the produced sentence.

The strongest finding so far from Study 2.1, together with evidence from Study 1 and other relevant research, is that difficulties in processing DO vs. PD sentences occur in patients when producing or repeating DO sentences with full lexical NP recipients, but these difficulties disappear with pronoun recipients. Study 2.2 then used two experiments to further explore the effect of pronoun recipients on dative sentence processing in a more natural setting of language processing.
Study 2.2

Effects of pronoun recipients and lexical accessibility on dative sentence production

The choice of structure during production of dative sentences clearly can be affected by lexical factors, as shown by the evidence discussed so far in the current study about the effect of pronoun recipients on DO sentence processing. Specially, corpus studies have found that when the recipient is a pronoun (her) rather than a full noun (e.g., nurse), it is more likely to appear in a DO structure (e.g. The waiter threw her a vase) rather than a PD structure (e.g., The waiter threw a vase to her), in both adult English speakers (Bresnan et al., 2007) and child speakers of English (de Marneffe et al., 2012). Comparing among DO sentences, DO sentences with pronoun recipients are also more frequent than DO sentences with full NP recipients in spoken English (Bresnan, 2007, p. 11). Consistent with the construction frequency data, Experiment 2.1 in the current study also found that DO sentences are more difficult to repeat than PD sentences only when the recipient is a full lexical NP, but not when the recipient is a pronoun. Therefore, pronoun recipients seem to make DO sentences easier to process than DO sentences with full NP recipients. The current Study 2.2 aims to further confirm this facilitating effect of pronoun recipients on DO sentence production, and explores the cognitive basis of this effect.

While some hypotheses have been put forward regarding the source of the preponderance of DO constructions with pronoun recipients relative to full NP recipients, there is currently a lack of empirical support for these hypotheses. A likely reason is that a pronoun is more accessible than a lexical NP both in terms of the referential concept and the lexical form. A pronoun recipient often refers to an animate entity previously mentioned in the discourse. Also, pronouns are short in length and high in word frequency, which would also ease retrieval. By
comparison, a lexical NP is often longer, with lower word frequency, more likely to be new information, and often inanimate if it is a theme in a dative sentence. Animacy and imageability of nouns affect their conceptual accessibility, the ease with which concepts of nouns can be retrieved from mental representations (Bock & Warren, 1985; McDonald et al., 1993). Besides these inherent properties, nouns can also gain derived conceptual accessibility in the discourse if they have been mentioned before, or assigned attentional focus (Prat-Sala & Branigan, 2000). One manipulation to assign attentional focus to a noun in the discourse is asking a question with the relevant referent as the topic (Prat-Sala & Branigan, 2000; Slevc, 2011). For example, in a picture depicting a dog biting cookies, asking a question like *What is going on with the dog?* would draw participants’ attention to the dog, while *What is going on with the cookies?* would assign discourse focus to the cookies and make the cookies conceptually more accessible. Conceptual accessibility should be distinguished from lexical accessibility, the ease with which the word form of referents can be retrieved. Lexically more accessible words are more frequent (Oldfield & Wingfield, 1965), shorter (Roelofs, 2002; Santiago, MacKay, & Palma, 2002) or more prototypical in a semantic category (Onishi et al., 2008).

There has been strong evidence showing that conceptual accessibility of words can affect the construction of sentence structure during production. In recalling sentences from long-term memory, speakers were more likely to change the original sentence structure when the result was to put the more accessible word in an earlier syntactic position, so that, for instance, *A refrigerator was purchased by a farmer* was recalled as *a farmer purchased a refrigerator,*

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11 One index of conceptual accessibility that also relates to lexical accessibility is givenness, i.e., whether a concept has been mentioned previously in the discourse (Bock & Irwin, 1980), especially when the same words were repeatedly used to refer to the same concept. In this case, a content word that has been mentioned before is more accessible both for its concept and lexical form.
putting the animate word before the inanimate (McDonald et al., 1993), and *The old hermit left the property to the university* was recalled as *The old hermit left the university the property*, putting the imageable word before the abstract word (Bock & Warren, 1985). Also, a word that is high in derived accessibility is more likely to be produced in a sentence structure that put the word early in a sentence. In picture description tasks, speakers were more likely to produce passive instead of active sentences to put the theme at the beginning of the sentence when the theme was made more accessible through questions asked about it (Prat-Sala & Branigan, 2000) or cued visually (Tomlin, 1997) in the prior context. A theme that was questioned about or mentioned previously was also more likely to be produced early in dative sentences, resulting in a greater tendency to produce PD sentences in picture description (Slevc, 2011). While conceptual accessibility can affect the order of major sentence constituents, lexical accessibility is generally believed to have an effect on word order only within a phrase (Tanaka et al., 2011).

For example, while speakers prefer *apples and lemons* to *lemons and apples*, placing the more prototypical word earlier within a phrase, there was no preference between *Shirts outsold hats* and *Hats were outsold by shirts*, when the two nouns different in prototypicality had different grammatical functions (Kelly, Bock, & Keil, 1986; Onishi et al., 2008). Similarly, speakers were more likely to place a shorter word before a longer word in a conjoined NP phrase, showing an effect of lexical accessibility on word order within a phrase, but there was no such effect of animacy, an index of conceptual accessibility (McDonald et al., 1993). Therefore, researchers generally assume that conceptual accessibility mainly affects functional assignment during sentence production, so that conceptually more accessible words are more likely to receive higher functional roles (e.g., subjects vs. objects), which in turn determines an earlier syntactic position (but see Tanaka et al., 2011; Yan & Dong, 2011 for evidence that conceptual
accessibility can directly affect word order, independent of functional assignment). By comparison, lexical accessibility does not directly affect functional assignment, but influences word order within a phrase, when the nouns in the phrase have similar grammatical functions. Evidence from corpus studies in both adult and child English speakers, however, found that apart from the pronoun status, contrasts in animacy, word length, givenness, and even definiteness (e.g., using the vs. a or an as the determiner) and number (singular vs. plural) between the recipient and the theme are all related to the relative frequency of DO vs. PD sentences, showing that both conceptual and lexical accessibility can affect sentence structure (Bresnan et al., 2007; de Marneffe et al., 2012). Thus, an approach which compromises different arguments above may be that both conceptual and lexical accessibility could potentially affect the choice of structure during sentence production, though the effect from conceptual accessibility is usually found to be stronger.

The cognitive basis of the accessibility effect on word order in sentence production is related to STM processes (Slevc, 2011). One possible mechanism, which is in line with the assumption of incrementality in language production (Kempen & Hoenkamp, 1987; Levelt, 1989; Wheeldon & Lahiri, 1997), is to view the accessibility effect as a result of a limited STM buffer (Baddeley, 2000; Just & Carpenter, 1992): To ease the cognitive burden during sentence production, speakers do not wait until complete planning of all words at all representation levels to start uttering the sentence. Instead, sentence planning proceeds in a cascading fashion, in that the speaker starts with conceptually planning a minimal unit that is conceptually most accessible, and sends it to the next stage of further processing while simultaneously retrieving other words.

But see Bock (1987) for some evidence that phonologically more accessible words were more likely to serve as subjects and affect the structure of transitive sentences. The paper suggested that there may be some feedback from the phonology level to the functional level, so that lexical accessibility can have some effect on the word order of major sentence constituents.
elements in earlier stages. Once the planning of the first unit is complete, the speaker can then start uttering these words, while simultaneously processing less accessible words to be produced in the later part of the sentence (see Martin et al., 2014 for a review of evidence for the scope of advance planning at different processing levels). Incremental processing may be helpful in avoiding the maintenance of too much information in STM buffer simultaneously while producing complex sentences. Another possible mechanism of the accessibility effect on word order is to view conceptually more accessible words as information that can be more easily activated/retrieved from long-term language representations. This complies with recent models of STM that adopts a cue-based retrieval approach (Badecker & Kuminiak, 2007; Lewis, Vasishth, & Van Dyke, 2006). From this view, STM includes very limited information in the focus of attention (perhaps one or two chunks; McElree, 2001), together with a larger portion of activated long term memory representations (Cowan, 1999; Oberauer, 2002; Unsworth & Engle, 2007). Retrieval of information from outside the focus of attention is based on task-relevant cues and is subject to interference when the cues partially match features of irrelevant information. In this sense, more accessible words are more activated and readily retrievable, but can also be affected by interference from other active information. Evidence from Slevec (2011) supported this account to view accessibility as active information in STM susceptible to interference, rather than as a result of a limited STM capacity. In a study exerting a STM load during description of dative pictures, Slevec (2011) found that conceptual accessibility effect (induced by previous emphasis of a given word) on word order was attenuated by a concurrent verbal STM load, but not by a spatial STM load, showing an interference between the more accessible word and actively maintained information in the STM. This finding is not consistent with the account that views the accessibility effect as a result of the need to produce more accessible words as soon as
possible to avoid taxing the limited STM capacity during production (Kempen & Hoenkamp, 1987; Levelt, 1989; Wheeldon & Lahiri, 1997), in which case an external STM load would have increased the accessibility because speakers would be under more pressure to produce words that were more accessible to reduce their cognitive burden.

The current study explored the effect of pronoun recipients on the choice of structure in dative sentence processing. Moreover, the study investigated the basis of the potential pronoun effects by examining the effects of accessibility and STM. Pictures depicting dative events were used to elicit target sentences. The questioning method used in (Prat-Sala & Branigan, 2000) and (Slevc, 2011) was used to manipulate the accessibility of one of the two objects in the target sentence. It was predicted that both patients and control speakers would show an accessibility effect on sentence structure, so that the proportion of DO structures produced should increase in the condition with more accessible recipients. Comparing effects between patients and control speakers could potentially illuminate the STM processes underlying the accessibility effect. Under a capacity-based account, patients are predicted to show a larger accessibility effect because they might rely more on producing accessible items to relieve their STM burden during sentence planning. The retrieval-based account would predict a smaller effect in patients, either because the activation of the more accessible word decays more rapidly, or because words activated in patients’ STM are more susceptible to interference than in control speakers (Hamilton & Martin, 2007). It was also predicted that both groups of participants should increase the use of DO structure when using pronoun recipients. If larger effects of pronoun recipients were found than accessibility effects, then it would suggest that additional factors, probably construction frequency, plays a role in shaping speakers’ choice of structure during sentence production.
Methods

Participants

Ten aphasic patients participated in Study 2.2 (mean age = 58), with nine of them having participated in the picture description task in Study 1.1. Six control speakers (mean age = 58) also participated in the study, five of them were female, and four of them had completed Study 1.1.

Materials and procedure

In this study participants described pictures in conversational settings. In Session 1, participants described all target pictures without the story contexts to provide a baseline measurement of the proportion of DO production. In Sessions 2 and 3 the accessibility of the recipient and theme nouns was manipulated during the conversation. In Session 4, the recipients were always made more accessible and had to be referred to using pronouns. There were two lists of materials for Sessions 2 and 3. List A, which was used for Session 2, consisted of 16 experimental trials in a story setting. Each experimental trial included presentation of a prime picture to manipulate recipient/theme accessibility and a target picture with a verb to elicit a dative sentence. Half of the trials increased the accessibility of recipients and other trials increased the accessibility of themes. List B, which was created for Session 3, had the same target pictures as List A, but the prime pictures differed from List A in the accessibility manipulation. For instance, a target picture which followed a prime picture making the theme more accessible in List A was paired to a prime picture making the recipient more accessible in List B. See Appendix L for a full list of experimental sentences.
An example trial in which the recipient was made more accessible was as follows:

*Recipient more accessible condition:*

**Experimenter:**

[Showing the prime picture (Figure 2.7a).] *The hen lays a lot of eggs every day. The boy is collecting eggs from the hen.*

[Showing the target picture (Figure 2.7b).] *The boy also helps to feed the hen and loves to play with the hen. What’s going on with the boy and the hen?*

**Participant:**

*The boy is offering the hen the worm. Or, The boy is offering the worm to the hen.*

As can be seen above, the recipient (*hen*) was mentioned several times in the prime picture, but the theme (*worm*) was never mentioned by the experimenter, establishing the recipient as given information and the theme as new information. Moreover, the question asked by the experimenter was about the agent and the recipient, therefore drawing participants’ attention to the recipient rather than to the theme. Both the givenness manipulation and the discourse focus manipulation made the recipient more accessible than the theme. Also, the question was shown visually above the target picture, so that even if patients had problems in perceiving the recipient in the question, or failed to maintain it in STM, they still might read the question, making the recipient more accessible for target sentence production.
An example trial in which the theme was made more accessible was as follows:

*Theme more accessible condition:*

**Experimenter:**

[Showing the prime picture (Figure 2.8a).] *The boy was fishing by the lake. He used worms as live bait.*

[Showing the target picture (Figure 2.8b).] *He had some extra worms left and took the worms back to the farm. What's going on with the boy and the worm?*

**Participant:**

*The boy is offering the hen the worm. Or, The boy is offering the worm to the hen.*
a.

Figure 2.7 Example pictures used in the recipient more accessible condition

a. Prime picture depicting the agent and the recipient.

b. Target picture, with the question about the recipient printed above the picture and the verb below the picture.
Figure 2.8 Example pictures used in the theme more accessible condition

a. Prime picture the agent and the theme.

b. Target picture, with the question about the theme printed above the picture and the verb below the picture.
Materials and procedure in the pronoun recipient condition were identical to the recipient more accessible condition, except that the use of pronouns was promoted. The pronoun was mentioned several times by the experimenter to refer to the recipient, and participants were instructed to always use pronouns to refer to the object asked about in the question. This manipulation was consistent with findings that within an episode, speakers are more likely to use pronouns to refer to the object that is the topic, or the object that draws attention (Tomlin, 1987; Tomlin & Pu, 1991). An example trial in which the recipient was made more accessible was as follows:

**Pronoun recipient more accessible condition:**

**Experimenter:**

[Showing the prime picture (Figure 2.7a).] The hen lays a lot of eggs every day. The boy is collecting eggs from her.

[Showing the target picture (Figure 2.7b).] The boy also helps to feed her and loves to play with her. What’s going on with the boy and her?

**Participant:**

The boy is offering her the worm. Or, The boy is offering the worm to her.

Each list had 16 filler transitive trials (e.g., the bear chased the hiker), where the agent or the theme was made more accessible in the prime picture. At the start of each session, there were three practice trials, including one transitive, one intransitive, and one dative target pictures.
Participants completed the four sessions with an interval of about a week. It took patients about 30 minutes and control speakers about 20 minutes to complete each session.

**Scoring and data analysis**

Participants’ responses were scored as PD, DO or others using the same criteria as in Study 1. Other responses were deleted from further analysis. Other responses constituted of about 5% of all responses in patients and less than 1% in controls.

**Results and discussion**

Participants’ proportions of DO sentence production are reported in Table 2.10. In the baseline condition, patients produced an average 23% of target sentences in the DO form. This was larger than the 13% of DO production in Exp. 1.1, though substantially lower than the 35% in control speakers in the current experiment\(^{13}\). The numerical increase of DO% from Experiment 1.1 to the baseline condition in the current study could be due to completely different sets of dative picture stimuli used in the two tasks. One apparent difference was that the dative event structures depicted in pictures in Exp. 1.1 were all very similar, with the theme always between the agent and the recipient (e.g., Figure 2.9a). By comparison, target pictures in the current experiment had more variation in the manner of depicting dative events, so that the theme was not always between the agent and the recipient (e.g., Figure 2.9b). Pictures in Exp. 1.1 might have strengthened participants’ tendency to adopt a default dative event structure of “an agent causing the movement of a theme towards a recipient”, in which the order of object aligns with the word order in a PD but not a DO sentence, causing a difficulty in planning a DO sentence (O'Grady & Lee, 2005). The larger increase of percent DO production from Exp. 1.1 to Exp. 2.2 in controls

\(^{13}\) Probably due to a small sample size, and the large variances in both groups, the 12% difference in the percent DO production in the baseline condition between patient and control group was not significant, \(t(14) = 1.01, p = .33\).
compared to patients may reflect a more flexible representation of the dative event structure in controls. Control speakers may be more adaptive in their order of conceptual processing of objects based on the specific dative event depicted in the pictures, while patients may have a more stereotyped conceptual representation of the dative event, and were more likely to rigorously follow the order of processing in the default event structure in sentence planning. Moreover, as was shown in Figure 2.2, healthy young speakers had a much larger percent DO production (36%) than older control speakers and patients (13% for both groups) in Exp. 1.1. It can be further assumed that young speakers have the most flexible way of conceptually planning the dative sentence, and were much less likely than both controls and patients to match their order of word production to the event structure in the pictures. Possibly, a larger STM capacity in young speakers than older speakers supported the misalignment in a default dative event structure and the word order in a DO sentence.
a. A sample picture in Exp. 1.1 (*the baker gave the hat to the swimmer*)

b. A sample picture used in Exp. 2.2 (*the mom is offering the milk to the baby*)

Figure 2.9 Different dative event structures depicted by target pictures used in Exp. 1.1 and Exp. 2.2
Another difference in materials that potentially caused more percent DO production might be the accessibility of recipients. As was discussed in the introduction of Study 2.1, the recipient nouns in Exp. 1.1 often share semantic features and could create semantic interference and retrieval difficulties. Moreover, further analysis showed that recipient nouns were also lower in word frequency than theme nouns. Recipients in Exp. 1.1 were all characters of different professions, and some of them (e.g., monk, ballerina, sailor) were not as frequent as common nouns in Exp. 2.2 (e.g., baby, boy). Consequently, the mean frequency of recipients in Exp. 1.1 in the Corpus of Contemporary American English (Davies, 2009, 2010) was 7528, compared to 27675 for recipients in Exp. 2.2, and the difference was significant ($t(30) = 2.39$, $p = .023$). By comparison, frequencies of themes in the two experiments were similar (mean = 42014 vs. 30444, $t(30) = .64$, $p = .53$). Therefore, speakers might have a larger tendency to produce DO sentences in Exp. 2.2 to put the more frequent (and lexically more accessible) recipient before the theme.

More DO production in the current can also be explained by the possibly larger self-priming compared to in Exp.1.1. The distribution density of dative target sentences was higher in the current task than in Exp. 1.1, making it more likely for participants to be self-primed by their own use of the less frequent DO structure. The baseline condition in the current study only had target dative pictures and an equal number of transitive pictures but no prime pictures, while in Exp. 1.1, there were other types of trials which were at least three times as frequent as dative trials, and each trial contained a prime sentence and a target sentence. Syntactic priming studies have shown that participants’ proportion of use of a certain structure can be influenced by their own cumulative frequency of production for that particular structure within the experimental session (Bernolet et al., 2016; Kaschak et al., 2011a), and the long-term priming effect can be especially larger for infrequent structures (Bernolet & Hartsuiker, 2010; Kaschak et al., 2011a).
It is not clear, though, how this account would explain the larger increase in percent DO production in controls than patients from Exp. 1.1 to the current task. Perhaps patients’ production of DO was more affected by the processing difficulty with DO sentences, so that the priming effect was more limited.
Table 2.10 Percent DO structure production and accessibility effects in Exp. 2.2

<table>
<thead>
<tr>
<th>Percent DO production</th>
<th>MLB</th>
<th>RK</th>
<th>FW</th>
<th>WC</th>
<th>PP</th>
<th>MK</th>
<th>GP</th>
<th>KC</th>
<th>DW</th>
<th>RF</th>
<th>Control Mean</th>
<th>Control Range</th>
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<tr>
<td>Exp. 1.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
<td>0.21</td>
<td>0.31</td>
<td>0.46</td>
<td>0.13</td>
<td>0.02-0.39</td>
<td></td>
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<tr>
<td>Baseline</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.25</td>
<td>0.19</td>
<td>0.38</td>
<td>0.63</td>
<td>0.13</td>
<td>0.60</td>
<td>0.35</td>
<td>0-0.69</td>
</tr>
<tr>
<td>Recipient-accessible</td>
<td>0.06</td>
<td>0.00</td>
<td>0.07</td>
<td>0.21</td>
<td>0.31</td>
<td>0.13</td>
<td>0.44</td>
<td>0.94</td>
<td>0.69</td>
<td>0.93</td>
<td>0.58</td>
<td>0.19-0.88</td>
</tr>
<tr>
<td>Theme-accessible</td>
<td>0.00</td>
<td>0.06</td>
<td>0.06</td>
<td>0.00</td>
<td>0.19</td>
<td>0.13</td>
<td>0.07</td>
<td>0.50</td>
<td>0.47</td>
<td>0.78</td>
<td>0.18</td>
<td>0-0.63</td>
</tr>
<tr>
<td>Pronoun-accessible</td>
<td>0.19</td>
<td>0.06</td>
<td>0.62</td>
<td>0.06</td>
<td>0.81</td>
<td>0.63</td>
<td>0.88</td>
<td>0.94</td>
<td>0.31</td>
<td>0.73</td>
<td>0.89</td>
<td>0.81-1</td>
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<tbody>
<tr>
<td>DO% (Recipient-baseline)</td>
<td>0.06</td>
<td>0.00</td>
<td>0.07</td>
<td>0.08</td>
<td>0.06</td>
<td>-0.06</td>
<td>0.06</td>
<td>0.31</td>
<td>0.55</td>
<td>0.33</td>
<td>0.23</td>
<td>0-0.50</td>
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<tr>
<td>PD% (Theme-baseline)</td>
<td>0.00</td>
<td>-0.06</td>
<td>-0.06</td>
<td>0.13</td>
<td>0.06</td>
<td>0.06</td>
<td>0.31</td>
<td>0.13</td>
<td>-0.33</td>
<td>-0.18</td>
<td>0.18</td>
<td>0-0.44</td>
</tr>
<tr>
<td>DO% (Pron.-baseline)</td>
<td>0.19</td>
<td>0.06</td>
<td>0.62</td>
<td>-0.07</td>
<td>0.56</td>
<td>0.44</td>
<td>0.50</td>
<td>0.31</td>
<td>0.18</td>
<td>0.13</td>
<td>0.53</td>
<td>0.19-0.81</td>
</tr>
</tbody>
</table>
Similar to what was found in Exp. 1.1 and Exp. 2.1a, patients’ difficulties in DO sentences were related to STM capacities. Correlating with STM measures, DO% in the baseline session correlated marginally with category probe spans ($r(8) = .58, p = .081$), but not with phonological STM composite scores or $d'$ scores in the sentence STM task ($rs < .37, ps > .30$) (see Figure 2.10 and Appendix M). Therefore, similar to Exp. 1.1, patients with better semantic STM produced more DO sentences in response to target pictures. Control speakers, however, showed no such effects, with correlations between percent DO production and semantic/phonological STM in the wrong direction ($-.10 < rs < -.07$).

![Figure 2.10 Plot of correlation between semantic STM and DO% in the baseline session in Exp. 2.2](image)

In terms of the accessibility effect on sentence structure, in the recipient more accessible condition, all but two patients (RK and MK) showed an increased tendency to put the recipient
before the theme, resulting in an average of 15% increase in DO% structure from the baseline condition. Four out of six control speakers also showed a similar effect, with the group mean at 23%, which was larger than the mean for the patients, though the range for controls was very large (0%-50%). In the theme more accessible condition, only 6 out of 10 patients showed an increase in the PD% compared to the baseline, and the group average was only 1%. By comparison, control speakers showed a 18% increase in the PD% from the baseline condition, with all but one control participants showing a positive effect. The null effect of the theme accessibility on sentence structure can be understood as a result of the high baseline PD% for many of the patients, which left less room to be further increased. Patients’ phonological STM capacities were also found to significantly correlate with the recipient accessibility effect, $r(8) = .63$, $p = .0498$ (see Figure 2.11). There was no such relationship in controls ($r (4) = .26$, $p = .61$). Taken together, both patients and control speakers showed a strong effect of recipient accessibility on sentence structure, so that they were more likely to put the more accessible recipient in an earlier syntactic position than the less accessible theme, resulting in an increased use of the DO structure. Due to the high baseline proposition of PD, making the theme more accessible did not further increase patients’ use of PD sentences, but control speakers did show an the accessibility effect (albeit smaller than the recipient accessibility effect). Findings also showed that better STM capacities increased the accessibility effect, supporting the hypothesis that the accessibility effect reflects increased activation level of the more accessible word, but this activation is probably transient and prone to interference from irrelevant information.
When pronouns were used to refer to the more accessible recipients, participants showed even stronger accessibility effects than when nouns were used for recipients. All but one patient (WC) showed an increased likelihood of producing a DO structure which put the pronoun recipient before the full NP theme relative to the baseline condition (mean pronoun accessibility effect = 29%). Control participants showed a huge 53% increase in DO% from the baseline, so that the vast majority (89%) of target sentences were produced in the DO structure. Unlike the accessibility effect, the pronoun recipient effect in patients did not have any relationship with any STM measure, with correlations close to zero or in the wrong direction and nonsignificant (-.44 < rs < .06, ps > .21; see Appendix M). There was also no relationship between STM measures and the pronoun effects in controls (-.14 < rs < .01).
Although both the recipient accessibility effect and the pronoun recipient effect were robust in patients and controls, the differences between these two effects in the size of the effects and their relationships to STM suggest that the preference for DO structures with pronoun vs. full NP recipients is related to accessibility, but cannot be completely attributed to it. What exactly are the commonalities and differences? Recipients in both conditions had higher degrees of conceptual accessibility than themes, because recipients were animate, had appeared in the prime pictures, and were the topics in the leading questions, while themes were inanimate, and had not appeared previously in the context. Also, recipients were lexically more accessible than themes, because the same word or pronoun was used in the discourse context and in the target sentence, while themes were never mentioned before the target sentence. However, differences between the two conditions can explain the larger magnitude of pronoun effects. First, the pronouns recipients were even more lexically accessible because they have a higher word frequency than nouns, and were also often shorter in length. Second, the high frequency of the DO construction with pronoun recipients may have an additive effect on the choice of structure, independent of the accessibility effect on the lexical level, although the frequent occurrence of this construction in English per se is probably a result of conceptual/lexical accessibility effects (Bresnan et al., 2007; de Marneffe et al., 2012). In other words, the accessibility effect at the lexical level is the origin of the high frequency of the DO construction with pronoun recipients, but as language users learn from their experience about this highly frequent construction, an abstract structural effect independent of lexical processing occurs, making speakers prefer this construction in dative sentence production, and disposing comprehenders to find this construction easier to understand in sentence processing.
The additive construction frequency effect in the pronoun recipient condition beyond any conceptual/lexical accessibility effect may also explain the lack of relationship between the pronoun recipient effect and STM measures, as this frequency effect probably reflects stronger construction representation in long-term memory. Also, maintaining the activation level of pronouns may not tax STM or the interference inhibition abilities too much, because pronouns are very short and highly frequent, and are therefore readily accessible for retrieval and not easily interfered with by irrelevant information. Nevertheless, the current study found a supporting role of phonological STM in the accessibility effect, shown by stronger effects in controls vs. patients, and a positive correlation between STM and the accessibility effect among patients. This is difficult to explain in an account which considers the accessibility effect as a way to relieve speakers’ cognitive burdens production, where a stronger effect might have been expected for patients due to their reduced STM capacity (c.f., Kempen & Hoenkamp, 1987; Levelt, 1989; Wheeldon & Lahiri, 1997). Instead, the accessibility effects depend on sustained activation of the lexical item, which can easily be interfered with by other information during lexical retrieval (Slevc, 2011). Patients with STM deficits probably suffer from more interference between activated items and irrelevant information (Hamilton & Martin, 2007). One point that needs attention is that only phonological STM but not semantic STM played a role in the accessibility effect in the current experiment whereas semantic STM seemed to play a role in the baseline condition. It is possible that lexical accessibility rather than conceptual accessibility had a larger effect on word order in the current paradigm, so that participants produced the recipient earlier mainly because it was easier to retrieve its word form, which had been mentioned several times in the discourse context, rather than because its concept was easier to access.
In sum, consistent with corpus studies showing that the DO construction is especially frequent when the recipient is a pronoun (Bresnan et al., 2007) and findings in Experiment 2.1 that patients were better able to repeat DO sentences with pronoun recipient than full NP recipients and the difficulty in repeating DO vs. PD only occurred when recipients were full NPs, in the current experiment, both patients and control speakers produced many more DO sentences when given the opportunities to use pronoun recipients. This pronoun recipient effect was partly due to the fact that pronouns were more accessible than full NPs both conceptually and lexically, because patients and controls showed a similar increase in DO production when full NP recipients were made more accessible. Additionally, construction frequency per se probably has an independent effect on the choice of specific construction during dative sentence production, supporting a usage-based approach stressing on the importance of language use experience in sentence processing (Gahl & Menn, 2016).

**General discussion**

Study 2 used four tasks to investigate factors affecting comprehension and production of dative sentences. In Exp. 2.1a, patients were better able to repeat PD sentence than DO sentences, and this structural effect correlated marginally with percent DO production in responses to target pictures in Exp. 1.1. Also, pronoun vs. full NP recipients tended to facilitate repetition of DO more than PD sentences, so that the difficulties with DO sentences that occurred with full NP recipient disappeared when pronoun recipients were used. These findings were consistent with data from corpus studies showing that DO sentences with pronoun recipients are much more frequent than DO sentences with full NP recipients and PD sentences with pronoun recipients (Bresnan et al., 2007; de Marneffe et al., 2012). Repetition of PD sentences was facilitated by pairs of the verb and the theme with a closer semantic relationship, but when the verb and the
theme were far in their semantic relationship, PD sentences were not easier to repeat than DO sentence. Phonological STM had a moderate correlation with the structural effect in sentence repetition, and a significant correlation with percent DO production in Exp. 1.1. These phonological STM effects, together with a moderate correlation between semantic STM and percent DO production in Exp. 1.1, showed a STM basis of the difficulties in processing DO sentences.

Exp. 2.1b used a grammaticality judgement tasks to specifically examine if difficulties in producing DO is related to more complex syntactic operations in DO vs. PD (e.g., Beck & Johnson, 2004; Bowers, 2002; Chomsky, 1975). Patients were slightly better in grammatical judgement on PD sentences vs. DO sentences, and had a tendency to incorrectly accept ungrammatical PD vs. DO sentences, therefore indicating a possible slight preference for a PD structure. There was also some evidence for better processing of DO sentences with pronoun recipients. However, these structural or pronoun effects were not related to percent DO production in Study 1.1, neither did semantic integration has any effect on syntactic processing of dative sentences. Therefore, there was little evidence that difficulties in producing DO are related to complex grammatical processing.

Exp. 2.1c further studied comprehension of dative sentences in a sentence anomaly judgment task. Similar like in Exp. 2.1b, patients were also more likely to incorrectly accept implausible PD vs. DO sentences. Patients also had poor performance on implausible provide-with sentences, possibly because of the developing of alternative plausible interpretations of these sentences. RTs in controls speakers, however, did show slower judgments on DO sentences than PD and provide-with sentences, indicating that not having a preposition as an explicit marker of grammatical function affected comprehension of DO sentences.
In a picture description task with a conversational setting, Exp. 2.2 provided strong evidence that the choice of the DO structure in dative sentence production is more likely when the recipient is a pronoun vs. a full NP, consistent with findings in Exp. 2.1a and corpus studies. This pronoun recipient effect can be partly attributed to the accessibility effect, in that pronoun recipients, which are conceptually and lexically more accessible than full NP recipients, are more likely to be produced early and result in DO vs. PD sentences. Moreover, the construction frequency per se may also have an effect on the choice of structure, so that when given the opportunity to use pronouns to refer to recipients, speakers are more likely to choose the more frequent DO construction. Both control and patient speakers showed robust pronoun recipient and accessibility effect, though effects in controls were considerably larger than patients. As in Exp. 1.1, patients with better semantic STM produced more DO sentences in the baseline condition, and patients with better phonological STM showed a larger accessibility effect, indicating an important role of STM in maintaining relevant information while producing DO sentences.

One notable finding in the current study is the different effects in different modalities. While strong effects of structure, pronoun recipients, semantic integration and STM have been found in tasks that involve production of dative sentences (Exp. 1.1, Exp. 2.1a and Exp. 2.2), less evidence for these effects were found in tasks that focused on input processing of dative sentences (Exp. 2.1b and Exp. 2.1c). As was discussed in the introduction, although syntax is assumed to be shared between sentence production and comprehension, different processes on other levels can result in unbalanced performance in the two modalities. For example, in Exp. 2.1b, there was no strong evidence that patients were selectively impaired in grammatical processing of the DO structure, but processing difficulties of DO sentences with full NP
recipients were found in other tasks that involve sentence production. The effect of semantic integration in Exp. 2.1a indicated that the structural processing difficulties could have origins at very early stages of conceptual planning in sentence production, e.g., a preference to conceptually plan the verb together with the theme before the planning of the recipient, a planning order consistent with the default dative event structure, which is different from the serial word order in the surface DO sentence structure (O'Grady & Lee, 2005). This processing difficulty of the DO structure can be relieved by conceptual accessibility of recipients, especially when the recipient is a pronoun and highly accessible for retrieval compared to the theme. Conceptual processing effects were normally found by previous research in sentence production (Bock & Warren, 1985; McDonald et al., 1993; Prat-Sala & Branigan, 2000; Slevc, 2011; Tanaka et al., 2011) rather than in sentence comprehension. Also, I raised the possibility in Exp. 2.1c that perception difficulties and misinterpretation of the function of prepositions might also played a role in sentence comprehension difficulties, but these were relevant just for input processing and wouldn’t have an effect on sentence production.
Overall conclusions

The current research provides valuable evidence to understand the choice of sentence structure during dative sentence production from a multi-factorial approach of sentence processing (Gahl & Menn, 2016; Menn & Bastiaanse, 2016). Specifically, findings from both Study 1 and Study 2 showed that interactions between lexical processing and structural processing factors affect speakers’ choice of dative structure. This is in line with the recent developments in sentence production research that both lexically-driven and structurally-driven processes are vital to sentence production processes (for a recent elaboration on distinguishing and relating lexically-driven and structurally-driven processes, see Bock & Ferreira, 2014). Figure 3 depicts basic components in a sentence production model.
At the very beginning is a message level in which speakers form the meaning to be conveyed. For planning of a dative sentence, this event message consists of the meaning of individual words (lexical concepts) like who caused what to move to whom. A default dative event structure of agent-verb-theme-recipient would have a locus at this stage. The next stage,
grammatical encoding, involves two major modules of processing at the lexical and structural level, respectively. For lexical processing, speakers need to select syntactic knowledge (lemmas) that corresponds to the lexical concepts, and retrieve morphological knowledge associated with each lemma. At this stage, conceptually and lexically more accessible words are selected early, and function words are retrieved to serve grammatical functions in the sentence. In the structural processing module, speakers build structures that specify functional relationships among lexical items and assign grammatical functions to lemmas (e.g. the subject moving the direct object to the indirect object). At this stage, conceptually more accessible words tend to be assigned higher grammatical functions. Then, speakers assemble the words into a linear string, and specify the fine-grained grammatical details of the sentence (e.g. tense, number, aspects etc.) through the process of inflection. After this, speakers encode phonological and phonetic information of the words and create prosodic patterns for the sentence. Finally, speakers articulated words and finish transferring the message to listeners.

Interactions could occur between lexical and structural processing modules, so that words that are more accessible are selected earlier, and assigned higher functions at the level of structural scaffolding, and then placed in earlier syntactic positions, and eventually affecting the choice of structure alternation. This is how the accessibility effect and the pronoun recipient effect on word order in dative sentences found in Study 2 occur, so that pronoun recipients as more accessible words are placed in front of full NP themes, resulting in DO sentences. A lexicalist account of syntactic representation (e.g., Pickering and Branigan, 1998) which assumes a close association between lexical and structural representations argues that sentence processing always involves a strong interaction between lexical and structural processing, causing a residual activation of the connection between the verb lemma and a particular structural representation,
which is the basis for the lexical boost (c.f., Chang et al., 2006 and others for an account which
does not assume strong interactions between lexical and structural processing). Findings in Study
1 are consistent with the lexicalist account of syntactic representations.

Beyond linguistic processes, STM can be important in supporting some processes of
sentence production. Both Study 1 and Study 2 provide consistent evidence that STM is also
critical in supporting dative sentence production, especially the more difficult DO structure. Exp.
1.1, Exp. 2.1a and Exp. 2.2 all found evidence that patients with better STM capacities were
better able to produce DO sentences. Also, the increase in DO production in the word array
paradigm in Exp. 1.2 also indicates that when the words remained visible on the screen and there
was no need to maintain words in STM, patients were more likely to choose the DO structure (35%
percent DO production on average). Patients’ percent DO production in Exp. 1.2 was related to
semantic STM ($r(6) = .74, p = .037$) and phonological STM (though nonsignificantly: $r(6) = .62,$
$p = .104$). Against the background of the sentence production model discussed above, STM
probably supports the mapping of the message to grammatical encoding, helping to resolve the
discrepancy in the processing order between a default dative event structure during the message
formulation stage and the surface sentence structure in a DO sentence during the grammatical
encoding stage. Moreover, the tendency to use the DO structure to produce highly accessible
recipients was also related to STM capacities, showing that maintaining the activation level of
accessible words in the stage of message formation depends on STM. Therefore, STM plays an
important role in linguistic processing at various stages in sentence production, and effectively
affected the choice of dative structure. By comparison, Study 1 found strong evidence that STM
is not relevant to the lexical boost of syntactic priming, countering the argument in many
syntactic priming studies (e.g., Chang et al, 2006; Hartsuiker et al., 2008). Findings in Study 1
can be explained by a lexicalist account of syntactic representation and processing (e.g., Pickering & Branigan, 1998), which assumes that the activation of the verb-structure association does not depend on explicit STM. Alternatively, the lexical boost can also be seen as a result of implicit learning of syntactic structure representations conditioned on specific verb items (Jaeger & Snider, 2013; Tooley & Traxler, 2010), which is independent of STM processes.

The relationships between different types of STM and sentence effects found across experiments suggested that processing difficulties with DO sentences may have basis on both the semantic and phonological level. Specifically, percent DO production was significantly related to phonological STM in Exp. 1.1 and to semantic STM in both Exp. 1.2 and Exp. 2.2. Although the correlations between percent DO production and semantic STM in Exp. 1.1 or phonological STM in Exp. 1.2 and 2.2 did not reach statistical significance, they were at least moderate in strength (rs = .41, .62 and .36, respectively). A larger sample size of patient participants is needed to obtain a more reliable pattern of results. The involvement of phonological STM seemed to be not consistent with previous findings that semantic, but not phonological STM deficits affected patients’ comprehension or production of complex phrases that had more content nouns (Martin & Freedman, 2001; Martin & He, 2004; Martin et al., 2004). One possibility for the role of phonological STM in producing a DO sentence may be that it helps speakers to temporarily maintain the word form of the theme, which has been both semantically and phonologically processed before the recipient, but has to be spoken out after the recipient in the sentence. This tendency might have been stronger in the syntactic priming tasks, reflecting a possibility that while the theme was planned and processed earlier than the recipient, a structural influence from a DO prime sentence could have prevented an earlier production of the theme, so that the participant could then produce a DO sentence with the recipient in front of the theme.
Consistent with this hypothesis, the phonological STM had much a weaker correlation with percent DO production in the baseline condition in Study 2.2, without any influence of prime sentences, compared to the two syntactic priming tasks in Study 1 \( (r_s = .36 \text{ vs. } .64 \text{ and } .62) \). The sentence repetition task in Exp. 2.1a also showed a stronger relationship with phonological STM (which was significant) than semantic STM (which was nonsignificant). But as discussed in Exp. 2.1a, this result was not unexpected given that sentence repetition primarily depends on verbatim recall and involves limited semantic processing. Finally, in Study 2.2, phonological but not semantic STM significantly correlated with the recipient accessibility effect. As the only previous empirical study investigating the STM basis of the accessibility effect, Slevc (2011) found that maintaining a STM load of two words attenuated the accessibility effect on the choice of dative structures in production. The current study provides further evidence that given information that receives speakers’ attention in the discourse is probably maintained in phonological STM, and the word form is more accessible for retrieval in sentence production. The findings could potentially argue against the long-held belief that only accessibility at the conceptual but not lexical level can affect order of major syntactic constituents in sentence production (Bock & Warren, 1985; McDonald et al., 1993; Onishi et al., 2008). However, more studies are needed to tease apart contributions from givenness (an index of lexical accessibility) and attentional salience (arguably an index of conceptual accessibility; Prat-Sala & Branigan, 2000) to the degree of accessibility in the current study. Moreover, it is possible that effects of conceptual accessibility measured by inherent features of words, like animacy or imageability, may be more related to semantic rather than phonological STM.
Findings from this dissertation also shows the importance of drawing evidence from cognitive neuropsychology research in shedding light on the human sentence processing models. Specifically, in Study 1.1, although control speakers showed no relationship between STM measures and the lexical boost, it could potentially be due to a lack of individual variances in STM measures, as for instance all controls showed high levels of performance in the sentence STM task. One might also raise the possibility that although the lexical boost indeed partially depends on STM, the size of the effects should not be linearly related to the STM capacities, and additional mechanisms could have played a role in causing more lexical boost effects in some control speakers than others. However, this possibility was refuted by findings in patients that the lexical boost can be obtained in patients despite severe STM deficits, and the size of the effects in patients was comparable to those in control speakers, and unrelated to degrees of STM deficits in patient. These findings provide strong evidence against a STM account of the lexical boost. Similarly, in Study 2.1, because control speakers showed performance of ceiling levels in three comprehension tasks, data from patients was especially important to explore effects of various manipulations in these tasks. In Study 2.2, while no role of STM was found in control speakers in percent DO production or in accessibility effects, STM capacities affected patients’ percent DO production and recipient accessibility effects. As was discussed in the introduction in Study 2, these findings again showed that difficulties with processing DO may be more apparent in patients with severe STM deficits. Nevertheless, I did find that control speakers produced fewer DO than young speakers in Exp. 1.1, phonological STM significantly correlated with percent DO production in controls in Exp. 1.2, and RT data from controls in Exp. 2.1c showed an advantage of parsing a dative sentence with a preposition, indicating that with a larger sample size of healthy older and younger speakers, an aging effect on dative sentence processing may be
obtained. This possible aging effect could also be potentially related to STM capacities, as older control speakers in the current dissertation did have somewhat weaker semantic and phonological STM capacities than young participants in Exp. 1.1 (category probe spans: 6.20 vs. 6.39; digit spans: 7.50 vs. 8.33).

In summary, Study 1 in the current dissertation found that aphasic patients showed a comparable lexical boost in syntactic priming as older control speakers, despite their varied degrees of deficits in maintaining information at different levels in STM. Effects of the lexical boost were not related to individual differences in STM capacities in patients or control speakers, showing that the lexical boost is a result of an automatic activation of the interaction between the verb and the structure, or reflecting a long-term implicit learning process independent of explicit memory. Both Study 1 and Study 2 found consistent evidence that patients have more difficulties producing or repeating DO sentences than PD sentences. The difficulties were related to STM capacities, and the ease of semantic integration between the verb and objects, suggesting that some of the difficulties can be attributed to differences between the word order in a DO sentences and the default dative event structure at the conceptual level. The use of more accessible or pronoun recipients can change the default order of lexical planning at the conceptual level, resulting in increased use of DO sentences. This pronoun recipient effect is consistent with findings in corpus studies that the frequency of DO constructions is conditioned on the type of recipient words, and the DO construction with a pronoun recipient is highly frequent in English. Taken together, the current research supports a multi-factorial approach of sentence processing which argues that successful production and comprehension of sentences require the combined results of lexical processing and structural processing, with the support of STM resources for some components of this interaction.
References


Davies, M. (2010). The Corpus of Contemporary American English as the first reliable monitor


Cognition, 6, 291-325.


cognitive sciences, 7, 219-224.


Phonology in Word Processing and Short-Term Memory. *Journal of Memory and Language, 41*, 3-29.


segregation of the neuronal infrastructure for speaking and listening revealed by functional MRI. *Psychological Science*, 22, 1173-1182.


Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and


Memory and Language, 65, 318-330.


Appendices

Appendix A

Patient descriptions

**DW.** Patient DW suffered a left hemisphere stroke 14 years prior to testing. A structural MRI scan revealed a lesion in left inferior frontal cortex, as well as a small lesion in the left middle frontal gyrus.

**FW.** Patient FW suffered from two strokes two years before testing. He had a lesion in the superior and middle temporal gyri which extends to the inferior frontal gyrus of the left hemisphere. There was some damage in the precentral gyrus of the right hemisphere as well.

**GP.** Patient GP suffered a stroke two years before testing. She had lesions in the inferior frontal lobe and in the cerebellum.

**KC.** Patient KC’s stroke occurred three years before testing. He had lesions that covered the superior and middle temporal gyri as well as parts of parietal such as the inferior parietal lobule.

**LC.** Patient LC had a stroke 11 years before testing. His lesion areas include the left parietal and superior temporal lobes, and part of the left posterior insula.

**MK.** Patient MK’s first and second strokes occurred six and 2.5 years prior to testing, resulting in a large lesion involving the superior temporal lobe and the superior and inferior parietal lobe.

**MLB.** Patient MLB had a stroke 5 years before the testing. His lesion mostly involves left superior and middle temporal gyri.
**PP.** Patient PP had a stroke less than two years before testing. His lesion is in the left superior temporal gyrus.

**RF.** Patient RF was 47 years old at the time of testing. She had a master’s degree. Her stroke occurred 2.5 years before the testing. A scan revealed a lesion in the inferior frontal gyrus mainly consisting of the pars triangularis and pars opercularis, and other lesions in the superior temporal lobe, the superior parietal lobule, and the post central gyrus.

**RI.** Patient RI was an 86-year-old man with a high-school degree. His stroke occurred 8 years before the testing. His lesion areas include the left temporal lobe and portions of the left parietal lobe.

**RK.** Patient RK had a stroke in her left tempo-parietal area 7 years prior to testing and had a large infarction in her left temporal lobe.

**RR.** Patient RR had a stroke 4 years before the testing. His lesion involves the left inferior frontal gyrus and portions of left temporal and parietal lobes.

**WC.** Patient WC’s stroke happened two years before the time of testing, leaving her with a lesion mainly involving the superior temporal lobe, the temporal pole, and parts of the inferior parietal lobule.
Appendix B

Sentence stimuli in Experiment 1.1

* Prime sentences are shown in the active or DO form, and in the different verb condition. The target sentences are shown in the passive or PD form.

**Transitive trials**

<table>
<thead>
<tr>
<th>Prime sentence</th>
<th>Target sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The policeman arrested the criminal.</td>
<td>The hiker was chased by a bear.</td>
</tr>
<tr>
<td>The fireman adopted the cat.</td>
<td>The skier was rescued by the dog.</td>
</tr>
<tr>
<td>The lion bit the toy.</td>
<td>The mailman was attacked by the dog.</td>
</tr>
<tr>
<td>The soccer player chased the ball.</td>
<td>The soldier was kicked by the cowboy.</td>
</tr>
<tr>
<td>The dog licked the child.</td>
<td>The surfer was knocked over by a wave.</td>
</tr>
<tr>
<td>The wave scared the swimmer.</td>
<td>The businessman was splashed by a car.</td>
</tr>
<tr>
<td>The girl told on the bully.</td>
<td>The burglar was slapped by the pirate.</td>
</tr>
<tr>
<td>The enemy followed the spy.</td>
<td>The farmer was captured by the spaceship.</td>
</tr>
<tr>
<td>the angry lion chased the zebra.</td>
<td>The hiker was hurt by a snake.</td>
</tr>
<tr>
<td>The boxer bought the punching bag.</td>
<td>The waiter was hit by the door.</td>
</tr>
<tr>
<td>The knight kissed the princess.</td>
<td>The surfer was rescued by a helicopter.</td>
</tr>
<tr>
<td>The waiter devoured the food.</td>
<td>The book was dropped by the pirate.</td>
</tr>
<tr>
<td>The water balloon hit the student.</td>
<td>The mailman was soaked by the rain.</td>
</tr>
<tr>
<td>The princess terrified the frog.</td>
<td>The swimmer was kissed by the waitress.</td>
</tr>
<tr>
<td>The community discovered the time capsule.</td>
<td>The skier was buried by an avalanche.</td>
</tr>
<tr>
<td>The skunk worried the gardener.</td>
<td>The farmer was sprayed by the sprinkler.</td>
</tr>
<tr>
<td>The kids mowed the grass.</td>
<td>The soldier was walked on by the chef.</td>
</tr>
<tr>
<td>The car scraped a telephone pole.</td>
<td>The golfer was struck by lightning.</td>
</tr>
<tr>
<td>The professor ignored the sleeping student.</td>
<td>The child was annoyed by the alarm clock.</td>
</tr>
<tr>
<td>The child's story pleased the parent.</td>
<td>The student was confused by the textbook.</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>The schoolboy disobeyed the teacher.</td>
<td>The boxer was tripped by the ballerina.</td>
</tr>
<tr>
<td>The employee closed the store.</td>
<td>The tourist was robbed by a monkey.</td>
</tr>
<tr>
<td>The thunderstorm exhausted the child.</td>
<td>The diver was frightened by a shark.</td>
</tr>
<tr>
<td>The ball surprised the catcher.</td>
<td>The clown was hit by the pie.</td>
</tr>
<tr>
<td>The story bored the reporter.</td>
<td>The tourist was amazed by the pyramids.</td>
</tr>
<tr>
<td>The artwork offended the critic.</td>
<td>The diver was amazed by the stingray.</td>
</tr>
<tr>
<td>The detective searched the suspect's house.</td>
<td>The TV was watched by the child.</td>
</tr>
<tr>
<td>The lemon juice soaked the fresh cut.</td>
<td>The businessman was stung by a bee.</td>
</tr>
<tr>
<td>The commuter took the bus.</td>
<td>The clown was chased by the lion.</td>
</tr>
<tr>
<td>The dog chewed the ball.</td>
<td>The ballerina was chased by the monk.</td>
</tr>
<tr>
<td>The politician debated the opponents.</td>
<td>The monk was attacked by the ballerina.</td>
</tr>
<tr>
<td>The rain drenched the picnic.</td>
<td>The golfer was cooled by the fan.</td>
</tr>
</tbody>
</table>

### Dative trials

<table>
<thead>
<tr>
<th><strong>Prime sentence</strong></th>
<th><strong>Target sentence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The bartender served the customer the drink.</td>
<td>The chef handing the ball to the boxer.</td>
</tr>
<tr>
<td>The catcher threw the pitcher the ball.</td>
<td>The chef giving the hat to the diver.</td>
</tr>
<tr>
<td>The boy lent his friend some money.</td>
<td>The cowboy is throwing the book to the sailor.</td>
</tr>
<tr>
<td>The author read the teacher the book.</td>
<td>The waitress selling the banana to the ballerina.</td>
</tr>
<tr>
<td>The mechanic sold the driver the part.</td>
<td>The cowboy bringing the jug to the clown.</td>
</tr>
<tr>
<td>The car dealer mailed the driver the keys.</td>
<td>The ballerina is throwing the glass to the swimmer.</td>
</tr>
<tr>
<td>The student told the teacher the excuse.</td>
<td>The ballerina giving the apple to the doctor.</td>
</tr>
<tr>
<td>The landlord rented the student the apartment.</td>
<td>The waitress offering the glass to the clown.</td>
</tr>
<tr>
<td>The waiter handed the diner the roll.</td>
<td>The monk throwing the hat to the burglar.</td>
</tr>
<tr>
<td>The father tossed the kid the frisbee.</td>
<td>The ballerina handing the apple to the boxer.</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>The waiter sold the diners the dessert.</td>
<td>The cowboy offering the banana to the burglar.</td>
</tr>
<tr>
<td>The guest mailed the graduate a gift.</td>
<td>The sailor bringing the money to the artist.</td>
</tr>
<tr>
<td>The congressmen told the voters the explanation.</td>
<td>The artist offering the paints to the monk.</td>
</tr>
<tr>
<td>The chef baked the birthday boy a cake.</td>
<td>The artist is selling the hat to the sailor.</td>
</tr>
<tr>
<td>The composer sang the king the song.</td>
<td>The ballerina giving the banana to the swimmer.</td>
</tr>
<tr>
<td>The teacher assigned the students the homework.</td>
<td>The pirate handing the ball to the swimmer.</td>
</tr>
</tbody>
</table>
Appendix C

Sentence stimuli in Experiment 1.2

* Prime sentences are shown in the active or DO form, and in the different verb condition. The target sentences are shown in the passive or DO form.

**Transitive trials**

<table>
<thead>
<tr>
<th>Prime sentence</th>
<th>Target sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>The car scraped the telephone pole.</td>
<td>The golfer was struck by lightning directly.</td>
</tr>
<tr>
<td>The soccer player chased the ball.</td>
<td>The soldier was kicked by the cowboy repeatedly.</td>
</tr>
<tr>
<td>The professor ignored the sleeping student.</td>
<td>The child was annoyed by the alarm sometimes.</td>
</tr>
<tr>
<td>The enemy followed the spy.</td>
<td>The farmer was captured by the spaceship secretly.</td>
</tr>
<tr>
<td>The child's story pleased the parent.</td>
<td>The student was confused by the textbook always.</td>
</tr>
<tr>
<td>The schoolboy disobeyed the teacher.</td>
<td>The boxer was almost tripped by the ballerina.</td>
</tr>
<tr>
<td>The employee closed the store.</td>
<td>The tourist was robbed by a monkey yesterday.</td>
</tr>
<tr>
<td>The thunderstorm exhausted the child.</td>
<td>The diver was really frightened by a shark.</td>
</tr>
<tr>
<td>The ball surprised the catcher.</td>
<td>The clown was hit by the pie almost.</td>
</tr>
<tr>
<td>The girl told on the bully.</td>
<td>The burglar was slapped by the pirate gently.</td>
</tr>
<tr>
<td>The story bored the reporter.</td>
<td>The tourist was amazed by the pyramids greatly.</td>
</tr>
<tr>
<td>The angry lion chased the zebra.</td>
<td>The hiker was hurt by a snake terribly.</td>
</tr>
<tr>
<td>The rain drenched the picnic.</td>
<td>The golfer was cooled by the fan quickly.</td>
</tr>
<tr>
<td>The lemon juice soaked the fresh cut.</td>
<td>The businessman was stung by a bee severely.</td>
</tr>
<tr>
<td>The princess terrified the frog.</td>
<td>The swimmer was kissed by the waitress</td>
</tr>
</tbody>
</table>
soundly.

| The boxer bought the punching bag. | The waiter was nearly hit by the door. |

**Dative trials**

<table>
<thead>
<tr>
<th><strong>Prime sentence</strong></th>
<th><strong>Target sentence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The committee awarded the researcher the grant.</td>
<td>The teacher gave the class the test.</td>
</tr>
<tr>
<td>The lawyer brought the partner the document.</td>
<td>The priest gave the orphan the gift.</td>
</tr>
<tr>
<td>The writer assigned the editor the novel.</td>
<td>The singer handed the fan the guitar.</td>
</tr>
<tr>
<td>The instructor promised the student the equipment.</td>
<td>The servant handed the prince the crown.</td>
</tr>
<tr>
<td>The curator sent the assistant the relic.</td>
<td>The barber offered the boy the haircut.</td>
</tr>
<tr>
<td>The senator assigned the advisor the policy.</td>
<td>The retailer offered the shopper the discount.</td>
</tr>
<tr>
<td>The florist tossed the husband the bouquet.</td>
<td>The coach passed the receiver the football.</td>
</tr>
<tr>
<td>The artist sent the patron the painting.</td>
<td>The waiter passed the customer the bread.</td>
</tr>
<tr>
<td>The architect sent the engineer the blueprint.</td>
<td>The agent sold the athlete the insurance.</td>
</tr>
<tr>
<td>The board awarded the reporter the honor.</td>
<td>The hunter sold the pilot the gun.</td>
</tr>
<tr>
<td>The vendor promised the manager the linen.</td>
<td>The cowboy showed the visitor the ranch.</td>
</tr>
<tr>
<td>The postman tossed the resident the parcel.</td>
<td>The sailor showed the friend the boat.</td>
</tr>
<tr>
<td>The detective served the suspect the soda.</td>
<td>The captain gave the pirate the treasure.</td>
</tr>
<tr>
<td>The associate brought the boss the cigar.</td>
<td>The uncle gave the nephew the bicycle.</td>
</tr>
<tr>
<td>The trainer brought the runner the shoes.</td>
<td>The mentor handed the traveler the compass.</td>
</tr>
<tr>
<td>The crew served the passenger the beverage.</td>
<td>The journalist handed the publisher the article.</td>
</tr>
<tr>
<td>The client brought the specialist the funds.</td>
<td>The analyst offered the chief the formula.</td>
</tr>
<tr>
<td>The aunt sent the youngster the turkey.</td>
<td>The technician passed the boxer the glove.</td>
</tr>
<tr>
<td>The widow sent the daughter the money.</td>
<td>The dealer passed the player the card.</td>
</tr>
<tr>
<td>The accountant taught the banker the lesson.</td>
<td>The broker offered the investor the bonds.</td>
</tr>
<tr>
<td>The columnist tossed the novice the newspaper.</td>
<td>The butcher sold the worker the steak.</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>The woman sent the plumber the cookie.</td>
<td>The cook sold the operator the salad.</td>
</tr>
<tr>
<td>The owner fed the pet the snack.</td>
<td>The musician showed the orchestra the violin.</td>
</tr>
<tr>
<td>The pitcher threw the catcher the baseball.</td>
<td>The pupil showed the tutor the homework.</td>
</tr>
<tr>
<td>The attendant served the golfer the peanut.</td>
<td>The gardener threw the housewife the tomato.</td>
</tr>
<tr>
<td>The sister sent the roommate the muffin.</td>
<td>The referee threw the wrestler the towel.</td>
</tr>
<tr>
<td>The sponsor brought the refugee the blanket.</td>
<td>The carpenter lent the cousin the hammer.</td>
</tr>
<tr>
<td>The composer brought the performer the piano.</td>
<td>The dancer lent the colleague the outfit.</td>
</tr>
<tr>
<td>The dad brought the daughter the toy.</td>
<td>The mechanic threw the builder the gadget.</td>
</tr>
<tr>
<td>The wife sent the consultant the potato.</td>
<td>The merchant threw the gentleman the sweater.</td>
</tr>
<tr>
<td>The lady served the neighbor the cocktail.</td>
<td>The inventor lent the niece the telescope.</td>
</tr>
<tr>
<td>The designer sent the model the dress.</td>
<td>The collector lent the family the antique.</td>
</tr>
</tbody>
</table>
## Appendix D

### Correlations in patients in Experiment 1.1 and 1.2

<table>
<thead>
<tr>
<th></th>
<th>Exp. 1.1 Priming effect</th>
<th>Exp. 1.1 Lexical boost</th>
<th>Exp. 1.2 Priming effect</th>
<th>Exp. 1.2 Lexical boost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category probe span</td>
<td>Pearson Correlation</td>
<td>-.147</td>
<td>-.041</td>
<td>.221</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.649</td>
<td>.900</td>
<td>.600</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Phono. composite score</td>
<td>Pearson Correlation</td>
<td>-.487</td>
<td>-.298</td>
<td>.319</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.108</td>
<td>.347</td>
<td>.441</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Sentence STM - DiffV</td>
<td>Pearson Correlation</td>
<td>-.697*</td>
<td>.292</td>
<td>.219</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.037</td>
<td>.445</td>
<td>.602</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Sentence STM - DiffS</td>
<td>Pearson Correlation</td>
<td>-.478</td>
<td>.367</td>
<td>.639</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.193</td>
<td>.331</td>
<td>.088</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Sentence STM - d'</td>
<td>Pearson Correlation</td>
<td>-.487</td>
<td>.376</td>
<td>.479</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.184</td>
<td>.319</td>
<td>.230</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Exp. 1.1 S repetition</td>
<td>Pearson Correlation</td>
<td>-.165</td>
<td>-.224</td>
<td>.606</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.608</td>
<td>.483</td>
<td>.111</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Exp. 1.1 Verb repetition</td>
<td>Pearson Correlation</td>
<td>-.214</td>
<td>-.226</td>
<td>.605</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.504</td>
<td>.479</td>
<td>.112</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Exp. 1.2 S repetition</td>
<td>Pearson Correlation</td>
<td>-.270</td>
<td>-.298</td>
<td>.377</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.518</td>
<td>.474</td>
<td>.357</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Exp. 1.2 Verb repetition</td>
<td>Pearson Correlation</td>
<td>-.258</td>
<td>-.306</td>
<td>.533</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.538</td>
<td>.461</td>
<td>.174</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
### Appendix E

**Correlations in control speakers in Experiment 1.1 and 1.2**

<table>
<thead>
<tr>
<th></th>
<th>Exp. 1.1 Priming effect</th>
<th>Exp. 1.1 Lexical boost</th>
<th>Exp. 1.2 Priming effect</th>
<th>Exp. 1.2 Lexical boost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category probe span</td>
<td>Pearson Correlation</td>
<td>.452</td>
<td>-.395</td>
<td>-.028</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.261</td>
<td>.333</td>
<td>.938</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Phono. composite score</td>
<td>Pearson Correlation</td>
<td>.599</td>
<td>.285</td>
<td>.595</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.117</td>
<td>.494</td>
<td>.070</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed).*
Appendix F

Plots of strongest correlations between lexical boost effects and STM measures in patients in Experiment 1.1 and 1.2

F1. Plot of correlation between lexical boost effects and $d'$ scores for overall performance in the sentence STM task in patients in Experiment 1.1

F2. Plot of correlation between lexical boost effects and $d'$ scores in the different verb condition in the sentence STM task in patients in Experiment 1.1
F3. Plot of correlation between lexical boost effects and $d'$ scores in the different structure condition in the sentence STM task in patients in Experiment 1.1

F4. Plot of correlation between lexical boost effects and phonological STM composite scores in controls in Experiment 1.2
F5. Plot of correlation between lexical boost effects and category spans in controls in Experiment 1.2
Appendix G

Experimental sentence stimuli in Experiment 2.1a (the sentence repetition task)

**DO-close**
- The teacher threw the driver the ball.
- The sailor mailed the farmer the package.
- The guest awarded the monk the prize.
- The manager taught the girl the skill.
- The senator told the shopper the story.
- The professor sent the worker the letter.
- The man assigned the prisoner the task.
- The pilot read the clown the book.

**PD-close**
- The teacher threw the ball to the driver.
- The sailor mailed the package to the farmer.
- The guest awarded the prize to the monk.
- The manager taught the skill to the girl.
- The senator told the story to the shopper.
- The professor sent the letter to the worker.
- The man assigned the task to the prisoner.
- The pilot read the book to the clown.

**DO-far**
- The teacher threw the driver the hat.
- The sailor mailed the farmer the jacket.
- The guest awarded the monk the gift.
- The manager taught the girl the rule.
- The senator told the shopper the reason.
- The professor sent the worker the apple.
- The man assigned the prisoner the seat.
- The pilot read the clown the law.

**PD-far**
- The teacher threw the hat to the driver.
- The sailor mailed the jacket to the farmer.
- The guest awarded the gift to the monk.
- The manager taught the rule to the girl.
- The senator told the reason to the shopper.
- The professor sent the apple to the worker.
- The man assigned the seat to the prisoner.
- The pilot read the law to the clown.
**DO-noun**

The waitress sold the ballerina the banana.
The doctor threw the burglar the cup.
The soldier offered the doctor the paints.
The nurse sent the dancer the pencil.
The guest brought the graduate the radio.
The boy lent the farmer the book.
The teacher handed the boxers the gift.
The sailor gave the students the song.

**PD-noun**

The waitress sold the banana to the ballerina.
The doctor threw the cup to the burglar.
The soldier offered the paints to the doctor.
The nurse sent the pencil to the dancer.
The guest brought the radio to the graduate.
The boy lent the book to the farmer.
The teacher handed the gift to the boxers.
The sailor gave the song to the students.

**DO-pronoun**

The waitress sold me the banana.
The doctor threw me the cup.
The soldier offered him the paints.
The nurse sent him the pencil.
The guest brought her the radio.
The boy lent her the book.
The teacher handed them the gift.
The sailor gave them the song.

**PD-pronoun**

The waitress sold the banana to me.
The doctor threw the cup to me.
The soldier offered the paints to him.
The nurse sent the pencil to him.
The guest brought the radio to her.
The boy lent the book to her.
The teacher handed the gift to them.
The sailor gave the song to them.
Appendix H

Correlations between effects in Experiment 2.1a (the sentence repetition task) with STM measures and proportions of DO responses in Experiment 1.1 (the picture description task)

<table>
<thead>
<tr>
<th>STM measures</th>
<th>DO% in Exp. 1.1</th>
<th>Category probe span</th>
<th>Composite score</th>
<th>Sentence STM d'</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO% in Exp. 1.1</td>
<td>Pearson Correlation 1</td>
<td>.410</td>
<td>.644*</td>
<td>.329</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.186</td>
<td>.024</td>
<td>.387</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

Effect of syntactic structure

<table>
<thead>
<tr>
<th>Effect</th>
<th>DO</th>
<th>PD</th>
<th>PD-DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO</td>
<td>Pearson Correlation .641*</td>
<td>.486</td>
<td>-.523</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.025</td>
<td>.109</td>
<td>.081</td>
</tr>
<tr>
<td>N</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>PD</td>
<td>Pearson Correlation .250</td>
<td>.414</td>
<td>.187</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.410</td>
<td>.159</td>
<td>.540</td>
</tr>
<tr>
<td>N</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>PD-DO</td>
<td>Pearson Correlation -.431</td>
<td>-.431</td>
<td>-.431</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.003</td>
<td>.142</td>
<td>.380</td>
</tr>
<tr>
<td>N</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

Effect of construction frequency

<table>
<thead>
<tr>
<th>Effect</th>
<th>PDN-DON</th>
<th>PDP-DOP</th>
<th>DOP-DON</th>
<th>PDP-PDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDN-DON</td>
<td>Pearson Correlation -.497</td>
<td>.091</td>
<td>-.281</td>
<td>.307</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>-.021</td>
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Effect of semantic integration

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* Significant at p < .05; ** Significant at p < .01
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*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).
Appendix I

Experimental sentence stimuli in Experiment 2.1b (the grammaticality judgment task)

(Ungrammatical sentence stimuli are italicized and marked with *.)

DO-close

*The sailors is mailing the farmer the letter.
*The pilot were reading the clown the book.
*The old man will reading the boxer the bible.
*The soldier has selling the janitor the tickets.
*The waitress mailed the pirate to the check.
*The guest awarded the monk to the prize.
*The professor is sending the worker to the e-mail.
*The artist read the swimmer to the passage.

The teacher threw the driver the ball.
The chefs are awarding the girls the contracts.
The manager was teaching the girl the skill.
The researcher taught the hiker the lesson.
The senator told the shopper the story.
The man assigned the prisoner the task.
The knight sold the burglar the merchandise.
The sheriff passed the farmer the salt.
DO-far

*The chefs is awarding the girls the options.
*The senator has telling the shopper the reason.
*The pilots will reading the clown the law.
*The knight are selling the burglar the pottery.
*The manager taught the girl to the rule.
*The researcher taught the hiker to the method.
*The professor is sending the worker to the apple.
*The man was assigning the prisoner to the seat.

The teacher threw the driver the hat.
The sailor mailed the farmer the photo.
The waitress mailed the pirate the key.
The guest awarded the monk the gift.
The old man was reading the boxer the menu.
The artist read the swimmer the proposal.
The soldier was selling the janitor the sugar.
The sheriff passed the farmer the wine.

DO-noun

*The diver selling his friend the orange.
*The prince passing the cowboys the knives.
*The knight are lending the professor the wallet.
*The burglar are mailing the businessman the bag.

*The girl tossing the policeman the bottle.

*The janitor are showing the clown the orange.

*The farmer throwing the princess the textbook.

*The monk were offering the children the keys.

*The tourist is selling the prince to the pear.

*The girls sold the swimmers to the shirts.

*The old man taught the kid to his experience.

*The gentleman passed the diver to the drink.

*The farmers passed the tourist to the wallet.

*The guests brought the graduate to the radio.

*The boy lent the farmer to the book.

*The teacher is handing the boxer to the gift.

*The girl handed the chefs to the keys.

*The king mailed the janitor to the computer.

*The soldier was awarding the clown to the apple.

*The artist awarded the mailman to the pen.

*The doctors were giving the salesmen to the alarm clocks.

*The monk tossed the businessmen to the umbrellas.

*The children tossed the artist to the bread.

*The ballerina showed the students to the shirts.

*The burglar showed the queen to the textbook.

*The knight loaned the waitress to the key.
*The mother read the son to the story.

*The sheriffs are reading the drivers to the regulations.

*The doctor threw the burglars to the cup.

*The soldier was offering the doctor to the paints.

*The nurses sent the dancers to the pencil.

*The janitor is sending the ballerinas to the bags.

The waitress sold the ballerina the banana.

The man was telling the pilot the news.

The researchers told the public the conclusion.

The police taught the thief the lesson.

The hiker passed the king the stick.

The burglar brought the queen the balloon.

The chef was bringing the salesman the news.

The waitress brought the boxers the balls.

The boy lent the diver the money.

The surfers lent the boxers the tools.

The hikers handed the knight the toy.

The swimmer handed the ballerina the vase.

The cowboys mailed the nurse the hat.

The policeman mailed the students the balloons.

The golfers awarded the pirate the radio.

The skier awarded the monks the cakes.

The sailor gave the student the fork.
The farmer gave the queen the glass.
The princess gave the sailor the box.
The swimmer tosses the princess the candy.
The pirates showed the nurse the pear.
The chef loaned the boy the jug.
The boxers loaned the salesman the pen.
The librarian was loaning the officer the cassettes.
The coach assigned the player the role.
The lecturer assigned the class the homework.
The cowboys threw the king the jug.
The businessman threw the golfer the bananas.
The policemen offered the soldier the tomato.
The mailman offered the skier the vase.
The artist sent the clown the alarm clock.
The pirate sent the student the computer.

**DO-pronoun**

*The researchers telling them the conclusion.*

*The waitress bringing them the balls.*

*The boy were lending her the money.*

*The skier were awarding them the cakes.*

*The sailor giving me the fork.*

*The pirates is showing her the pear.*
*The coach were assigning me the role.
*The mailman offering her the vase.
*The man told me to the news.
*The chef brought him to the news.
*The surfers lent them to the tools.
*The cowboys mailed me to the hat.
*The princess gave him to the box.
*The librarian loaned them to the cassettes.
*The cowboy threw me to the bananas.
*The policemen were offering him to the tomato.
*The diver sold she the orange.
*The police taught he the lesson.
*The hiker was passing he the stick.
*The burglar brought she the balloon.
*The knight lent he the wallet.
*The swimmer handed she the vase.
*The policeman is mailing they the balloons.
*The golfers awarded I the radio.
*The farmer gave she the glass.
*The swimmer tosses I the candy.
*The janitor showed he the orange.
*The boxers loaned he the pen.
*The lecture assigned they the homework.
*The cowboys are throwing he the jug.

*The monk offered they the keys.

*The pirate sent she the computer.

The waitress sold me the banana.

The tourist sold him the pear.

The girls are selling them the shirts.

The old man taught her his experience.

The gentleman passed me the drink.

The farmers passed her the wallet.

The prince passed them the knives.

The guests brought me the radio.

The boy lent me the book.

The teacher handed me the gift.

The hikers are handing him the toy.

The girl handed them the keys.

The king mailed her the computer.

The burglar mailed him the bag.

The soldier awarded her the apple.

The artist is awarding him the pen.

The doctors gave them the alarm clocks.

The girl tosses him the bottle.

The monk was tossing them the umbrellas.

The children tossed her the bread.
The ballerina showed them the shirts.
The burglar showed me the textbook.
The chef is loaning me the jug.
The knight loaned her the key.
The mother read him the story.
The sheriffs read them the regulations.
The doctor threw them the cup.
The farmer sold her the textbook.
The soldier offered me the paints.
The nurses were sending me the pencils.
The artist sent him the alarm clock.
The janitor sent them the bags.

**PD-close**

*The teacher are throwing the ball to the driver.*

*The sailors was mailing the letter to the farmer.*

*The chefs will awarding the contracts to the girls.*

*The soldier has selling the tickets to the janitor.*

*The guests are awarding the prize the monk.*

*The researcher taught the lesson the hiker.*

*The artist read the passage the swimmer.*

*The sheriff passed the salt the farmer.*

The waitress mailed the check to the pirate.
The manager was teaching the skill to the girl.
The senator told the story to the shopper.
The professor sent the e-mail to the worker.
The man assigned the task to the prisoner.
The pilot read the book to the clown.
The old man was reading the bible to the boxer.
The knight sold the merchandise to the burglar.

**PD-far**

*The teacher were throwing the hat to the driver.*
*The senator will telling the reason to the shopper.*
*The old man has reading the menu to the boxer.*
*The knight are selling the pottery to the burglar.*
*The waitress mailed the key the pirate.*
*The manger taught the rule the girl.*
*The man was assigning the seat the prisoner.*
*The sheriff passed the wine the farmer.*

The sailor mailed the photo to the farmer.
The guests were awarding the gift to the monk.
The chefs awarded the options to the girls.
The researcher taught the method to the hiker.
The professor sent the apple to the worker.
The pilot read the law to the clown.
The artist read the proposal to the swimmer.

The soldier sold the sugar to the janitor.

**PD-noun**

*The waitress selling the banana to the ballerina.*

*The hiker were passing the stick to the king.*

*The hikers handing the toy to the knight.*

*The policeman mailing the balloons to the students.*

*The farmer are giving the glass to the queen.*

*The chef are loaning the jug to the boy.*

*The cowboys is throwing the jug to the king.*

*The artist sending the alarm clock to the clown.*

*The tourist sold the pear the prince.*

*The girls sold the shirts the swimmers.*

*The man told the news the pilot.*

*The gentleman is passing the drink the diver.*

*The farmers passed the wallet the tourist.*

*The guests are bringing the radio the graduate.*

*The boy lent the book the farmer.*

*The surfers were lending the tools the boxers.*

*The girl handed the keys the chefs.*

*The cowboys were mailing the hat the nurse.*

*The soldier awarded the apple the clown.*
*The artist awarded the pen the mailman.

*The princess gave the box the sailor.

*The doctors gave the alarm clocks the salesmen.

*The monk tossed the umbrellas the businessmen.

*The ballerina was showing the shirts the students.

*The burglar showed the textbook the queen.

*The librarian loaned the cassettes the officer.

*The mother read the story the son.

*The doctor threw the cup the burglars.

*The businessman is throwing the bananas the golfer.

*The soldier offered the paints the doctor.

*The nurses sent the pencils the dancer.

*The janitor sent the bags the ballerinas.

The diver sold the orange to his friend.

The researchers told the conclusion to the public.

The police taught the lesson to the thief.

The old man taught his experience to the kid.

The prince passed the knives to the cowboys.

The burglar brought the balloon to the queen.

The chef brought the news to the salesman.

The waitress brought the balls to the boxers.

The knight lent the wallet to the professor.

The boy lent the money to the diver.
The teacher handed the gift to the prince.
The swimmer handed the vase to the ballerina.
The king mailed the computer to the janitor.
The burglar mailed the bag to the businessman.
The golfers awarded the radio to the pirate.
The skier is awarding the cakes to the monks.
The sailor gave the fork to the student.
The swimmer tosses the candy to the princess.
The girl tosses the bottle to the policeman.
The children were tossing the bread to the artist.
The janitor showed the orange to the clown.
The pirates showed the pear to the nurse.
The knight is loaning the key to the waitress.
The boxers loaned the pen to the salesman.
The coach assigned the role to the player.
The lecturer was assigning the homework to the class.
The sheriffs read the regulations to the drivers.
The farmer threw the textbook to the princess.
The policemen offered the tomato to the soldier.
The mailman is offering the vase to the skier.
The monk offered the keys to the children.
The pirate sent the computer to the student.
PD-pronoun

*The police teaching the lesson to him.
*The burglar are bringing the balloon to her.
*The swimmer were handing the vase to her.
*The golfers awarding the radio to me.
*The swimmer are tossing the candy to me.
*The boxers loaning the pen to him.
*The lecturer are assigning the homework to them.
*The pirate sending the computer to her.
*The old man is teaching his experience her.
*The chef brought the news him.
*The teacher handed the gift me.
*The king was mailing the computer her.
*The children tossed the bread her.
*The knight loaned the key her.
*The sheriffs read the regulations them.
*The policemen offered the tomato him.
*The waitress sold the banana to I.
*The researchers told the conclusion to they.
*The prince passed the knives to they.
*The waitress brought the balls to they.
*The boy lent the money to she.
*The hikers handed the toy to he.

*The burglar mailed the bag to he.

*The skier awarded the cakes to they.

*The sailor gave the fork to I.

*The girl tosses the bottle to he.

*The pirates showed the pear to she.

*The chef loaned the jug to I.

*The coach assigned the role to I.

*The farmer threw the textbook to she.

*The mailman offered the vase to she.

*The artist sent the alarm clock to he.

The diver was selling the orange to her.

The tourist sold the pear to him.

The girls sold the shirts to them.

The man told the news to me.

The gentleman passed the drink to me.

The farmers are passing the wallet to her.

The hiker passed the stick to him.

The guests brought the radio to me.

The boy lent the book to me.

The knight lent the wallet to him.

The surfers lent the tools to them.

The girl was handing the keys to them.
The cowboys mailed the hat to me.
The policeman mailed the balloons to them.
The soldier awarded the apple to her.
The artist awarded the pen to him.
The farmer gave the glass to her.
The princess was giving the box to him.
The doctors gave the alarm clocks to them.
The monk tossed the umbrellas to them.
The janitor showed the orange to him.
The ballerina showed the shirts to them.
The burglar was showing the textbook to me.
The librarian loaned the cassettes to them.
The mother is reading the story to him.
The doctor was throwing the cup to them.
The cowboys threw the jug to him.
The businessman threw the bananas to me.
The soldier offered the paints to me.
The monk is offering the keys to them.
The nurses sent the pencils to me.
The janitor sent the bags to them.
Appendix J

Correlations between effects in Experiment 2.1b (the grammaticality judgement task) with STM measures and proportions of DO responses in Experiment 1.1 (the picture description task)

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<th>STN measures</th>
<th>DO% in Exp. 1.1</th>
<th>Category probe span</th>
<th>Phono. Composite score</th>
<th>Sentence STM d'</th>
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### Effect of syntactic structure

- **DO**
  - Pearson Correlation: 0.135
  - Sig. (2-tailed): 0.692
  - n: 11
- **PD**
  - Pearson Correlation: 0.295
  - Sig. (2-tailed): 0.378
  - n: 11
- **PD-DO**
  - Pearson Correlation: 0.404
  - Sig. (2-tailed): 0.218
  - n: 11

### Effect of construction frequency

- **PDN-DON**
  - Pearson Correlation: 0.300
  - Sig. (2-tailed): 0.370
  - n: 11
- **PDP-DOP**
  - Pearson Correlation: 0.132
  - Sig. (2-tailed): 0.698
  - n: 11
- **DOP-DON**
  - Pearson Correlation: -0.063
  - Sig. (2-tailed): 0.854
  - n: 11
- **PDP-PDN**
  - Pearson Correlation: -0.241
  - Sig. (2-tailed): 0.475
  - n: 11

### Effect of semantic integration

- **PDC-DOC**
  - Pearson Correlation: 0.661*
  - n: 11
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<td>.716</td>
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## Appendix K

**Experimental sentence stimuli in Experiment 2.1c (the sentence anomaly judgment task)**

(Implausible sentence stimuli are italicized and marked with *.)

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<td>researcher</td>
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<td>The lawyer brought the partner the</td>
<td>The lawyer brought the document to the</td>
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<td>The editor assigned the writer the topic</td>
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<td>The instructor promised the student the</td>
<td>The instructor promised the equipment to the</td>
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<td>The senator assigned the policy to the advisor</td>
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<td>The architect sent the engineer the</td>
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<td>The associate brought the boss the</td>
<td>The associate brought the cigar to the boss</td>
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</table>
The sister sent the roommate the muffin
The client brought the specialist the funds
The uncle sent the youngster apples
The widow sent the daughter the money
The accountant taught the banker the lesson
The columnist tossed the novice the newspaper
The woman sent the plumber the cookie
The owner fed the pet the snack
The pitcher threw the catcher the baseball
The princess gave the sailor the box
The mailman offered the woman the vase
*The sailor gave the fork the student
*The man was telling the news the pilot
*The boxers loaned the pen the salesman
*The chef loaned the jug the boy
*The policeman mailed the balloon the student
*The researchers told the conclusion the public
*The policemen offered the tomato the soldier
*The pirate sent the computer the student

The sister sent the muffin to the roommate
The client brought the funds to the specialist
The uncle sent apples to the youngster
The widow sent the money to the daughter
The accountant taught the lesson to the banker
The columnist tossed the newspaper to the novice
The woman sent the cookie to the plumber
The owner fed the snack to the pet
The pitcher threw the baseball to the catcher
The princess gave the box to the sailor
The mailman offered the vase to the woman
*The sailor gave the student to the fork
*The man was telling the pilot to the news
*The boxers loaned the salesman to the pen
*The chef loaned the boy to the jug
*The policeman mailed the student to the balloon
*The researchers told the public to the conclusion
*The policemen offered the soldier to the tomato
*The pirate sent the student to the computer
*The businessman threw the banana the golfer
*The businessman threw the golfer to the banana

*The waitress brought the ball the boxer
*The waitress brought the boxer to the ball

*The swimmer handed the vase the ballerina
*The swimmer handed the ballerina to the vase

*The waitress sold the banana the prince
*The waitress sold the prince to the banana

*The artist sent the clock the clown
*The artist sent the clown to the clock

*The farmer gave the glass the queen
*The farmer gave the queen to the glass

*The surfer lent the tool the boxer
*The surfer lent the boxer to the tool

*The librarian was loaning the cassette the officer
*The librarian was loaning the officer to the cassette

*The skier awarded the cake the monk
*The skier awarded the monk to the cake

*The cowboys mailed the hat the nurse
*The cowboys mailed the nurse to the hat

*The boy lent the money the diver
*The boy lent the diver to the money

*The pirates showed the treasure the nurse
*The pirates showed the nurse to the treasure

*The coach showed the trick the player
*The coach showed the player to the trick

*The swimmer tosses the candy the princess
*The swimmer tosses the princess to the candy

*The lecturer showed the homework the class
*The lecturer showed the class to the homework

*The cowboys threw the jug the king
*The cowboys threw the king to the jug

PD Provide-with

The critic is crediting the dessert to the chef
The critic is crediting the chef with the dessert
The mom provided the meal to the kid
The intern presented the results to the department
The boy left the bone to the dog
The advisor provided the suggestions to the woman
The bank supplied cards to clients
The family entrusted the dog to the neighbor
The farm supplied fruits to the village
The lake supplied water to the town
The manager left the problem to the team
The government provided passports to citizens
The architect presented the design to the museum
The prince entrusted the baby to the general
The referee provided the ball to the player
The assistant presented the report to the lawyer
The landlord left the furniture to the tenant
The policeman provided the help to the girl
The city supplied the helmets to the policemen

The mom provided the kid with the meal
The intern presented the department with the results
The boy left the dog with the bone
The advisor provided the woman with the suggestions
The bank supplied clients with cards
The family entrusted the neighbor with the dog
The farm supplied the village with fruits
The lake supplied the town with water
The manager left the team with the problem
The government provided citizens with passports
The architect presented the museum with the design
The prince entrusted the general with the baby
The referee provided the player with the ball
The assistant presented the lawyer with the report
The landlord left the tenant with the furniture
The policeman provided the girl with the help
The city supplied the policemen with the helmets
The principle credited the achievements to the teacher
The store supplied materials to the artist
The criminal supplied drugs to the dealer
The king left the disaster to the empire
The company provided the document to the employee
The scientist presented the research to the audience
*The parents entrusted the kindergarten to their kids
*The mayor is providing the sick children to the donations
*The parents are presenting the kidnapper to the ransom
*The teacher provided the students to the homework
*The seller is providing the customer to the merchandise
*The organization presented the applicant to the certificate
*The general is crediting the hero to the prize

The principle credited the teacher with the achievements
The store supplied the artist with materials
The criminal supplied the dealer with drugs
The king left the empire with the disaster
The company provided the employee with the document
The scientist presented the audience with the research
*The parents entrusted their kids with the kindergarten
*The mayor is providing the donations with the sick children
*The parents are presenting the ransom with the kidnapper
*The teacher provided the homework with the students
*The seller is providing the merchandise with the customer
*The organization presented the certificate with the applicant
*The general is crediting the prize with the hero
*The cow is supplying the puppies to the milk

*The pump is supplying the car to the gas

*The team supplied players to uniforms

*The hotel provided the guest to the pass

*The designer is presenting the audience to the dress

*The farmer supplied the restaurant to apples

*The company provided the winner to the awards

*The reporter presented the firefighters to the medals

*The official presented the public to the regulation

*The doctor provided the patient to the treatment

*The office presented the visitor to the permit

*The businessman entrusted the safe box to the fortune

*The factory supplied the market to the products

*The cow is supplying the milk with the puppies

*The pump is supplying the gas with the car

*The team supplied uniforms with players

*The hotel provided the pass with the guest

*The designer is presenting the dress with the audience

*The farmer supplied apples with the restaurant

*The company provided the awards with the winner

*The governor presented the medals with the firefighters

*The official presented the regulation with the public

*The doctor provided the treatment with the patient

*The office presented the permit with the visitor

*The businessman entrusted the fortune with the safe box

*The factory supplied the products with the market
*The machine supplied the pet to the food  *The machine supplied the food with the pet

*The job candidate presented the interviewer to the resume  *The job candidate presented the resume with the interviewer

*The company supplied the market to the stock  *The company supplied the stock with the market

*The prime minister presented the nation to the report  *The prime minister presented the report with the nation
Appendix L

Experimental stimuli in each condition in Experiment 2.2

The recipient more accessible condition

<table>
<thead>
<tr>
<th>#</th>
<th>Target sentence</th>
<th>Recipient-given</th>
<th>Target picture</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The policeman is passing the soldier the hat.</td>
<td>The soldier is very upset because he lost something in the street.</td>
<td>The policeman has been able to help the soldier.</td>
<td>What's going on with the policeman and the soldier?</td>
</tr>
<tr>
<td>2</td>
<td>The cowboy is sending the sailor the book.</td>
<td>The sailor wants to read about Asia because he will be sailing to Asia soon.</td>
<td>The sailor came to the cowboy for help.</td>
<td>What's going on with the cowboy and the sailor?</td>
</tr>
<tr>
<td>3</td>
<td>The cowboy is handing the monk an apple.</td>
<td>The monk is hungry, so he went to the market to buy some food.</td>
<td>The monk saw the cowboy with a lot of good stuff.</td>
<td>What's going on with the cowboy and the monk?</td>
</tr>
<tr>
<td>4</td>
<td>The policeman is sending the boxer a cake.</td>
<td>The boxer is 25 years old today. He practices every day—even on his birthday.</td>
<td>The boxer's friend, the policeman, came to celebrate his birthday.</td>
<td>What's going on with the policeman and the boxer?</td>
</tr>
<tr>
<td>5</td>
<td>The nun is handing the doctor the jug.</td>
<td>The doctor's office is on fire. He is running out to get some help.</td>
<td>The doctor ran into the nun, and ask her for help.</td>
<td>What's going on with the nun and the doctor?</td>
</tr>
<tr>
<td>6</td>
<td>Cindy is showing Paul the picture.</td>
<td>Cindy and Paul are good friends.</td>
<td>They came to Paul's home to play.</td>
<td>What's going on with Cindy and Paul?</td>
</tr>
<tr>
<td>7</td>
<td>The boy is offering the hen the worm.</td>
<td>The hen lays a lot of eggs every day. The boy is collecting eggs from her.</td>
<td>The boy also helps to feed the hen and loves to play with the hen.</td>
<td>What's going on with the boy and the hen?</td>
</tr>
<tr>
<td>8</td>
<td>The girl is passing the boy the car.</td>
<td>The boy is sitting on the ground. He doesn't have anything to play with.</td>
<td>The girl comes to play with the boy.</td>
<td>What's going on with the girl and the boy?</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>9</td>
<td>The mom is offering the baby the milk.</td>
<td>The baby is only 12 months old, and he is crawling in this picture.</td>
<td>The baby's mom loves him a lot.</td>
<td>What's going on with the mom and the baby?</td>
</tr>
<tr>
<td>10</td>
<td>Jane is handing Peter the shoe.</td>
<td>Peter loves sports. He is running around in this picture.</td>
<td>Peter runs into Jane, who just finished a soccer game.</td>
<td>What's going on with Jane and Peter?</td>
</tr>
<tr>
<td>11</td>
<td>The boy is giving the snowman the scarf.</td>
<td>The snowman is standing in the snow. He feels really cold.</td>
<td>The boy comes to play with the snowman.</td>
<td>What's going on with the boy and the snowman?</td>
</tr>
<tr>
<td>12</td>
<td>The alligator is sending the elephant a violin.</td>
<td>The elephant likes music. He plays all kinds of musical instruments.</td>
<td>His friend, the alligator, runs into the room to play with the elephant.</td>
<td>What's going on with the alligator and the elephant?</td>
</tr>
<tr>
<td>13</td>
<td>The mom is offering the baby the scarf.</td>
<td>It's cold outside. The mom and the baby are looking out of the window.</td>
<td>The baby wants to go outside and play.</td>
<td>What's going on with the mom and the baby?</td>
</tr>
<tr>
<td>14</td>
<td>The zookeeper is giving the seal the fish.</td>
<td>The seal lives happily in the zoo. He likes to play with children.</td>
<td>The zookeeper takes good care of the seal.</td>
<td>What's going on with the zookeeper and the seal?</td>
</tr>
<tr>
<td>15</td>
<td>The boy is showing the duck the pacifier.</td>
<td>The duck lives by the lake. He is not friendly to others.</td>
<td>The boy tries to play with the duck.</td>
<td>What's going on with the boy and the duck?</td>
</tr>
<tr>
<td>16</td>
<td>Mary is lending Tommy the skates.</td>
<td>Tommy fell off his scooter.</td>
<td>Tommy is not hurt, but his scooter is broken.</td>
<td>What's going on with the girl and Tommy?</td>
</tr>
</tbody>
</table>
The theme more accessible condition

<table>
<thead>
<tr>
<th>#</th>
<th>Target sentence</th>
<th>Theme-given</th>
<th>Target picture</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The policeman is passing the soldier the hat.</td>
<td>The policeman went into a store to buy a hat.</td>
<td>He bought the hat as a gift.</td>
<td>What's going on with the policeman and the hat?</td>
</tr>
<tr>
<td>2</td>
<td>The cowboy is sending the sailor the book.</td>
<td>The cowboy is writing a book on healthy diet.</td>
<td>He made a copy of the book.</td>
<td>What's going on with the cowboy and the book?</td>
</tr>
<tr>
<td>3</td>
<td>The cowboy is handing the monk an apple.</td>
<td>The cowboy is selling apples in the market.</td>
<td>His apples are really sweet.</td>
<td>What's going on with the cowboy and the apple?</td>
</tr>
<tr>
<td>4</td>
<td>The policeman is sending the boxer a cake.</td>
<td>This is a delicious home-made birthday cake with candles on it.</td>
<td>The policeman and his wife made the cake together.</td>
<td>What's going on with the policeman and the cake?</td>
</tr>
<tr>
<td>5</td>
<td>The nun is handing the doctor the jug.</td>
<td>The nun likes gardening. She uses a jug to water the plants.</td>
<td>Here is the jug again, the nun is using it to teach the doctor how to do gardening.</td>
<td>What's going on with the nun and the jug?</td>
</tr>
<tr>
<td>6</td>
<td>Cindy is showing Paul the picture.</td>
<td>Cindy is very good at drawing pictures. She just finished one.</td>
<td>She wanted to show off her picture.</td>
<td>What's going on with Cindy and the picture?</td>
</tr>
<tr>
<td>7</td>
<td>The boy is offering the hen the worm.</td>
<td>The boy was fishing by the lake. He used worms as live baits.</td>
<td>He has some extra worms left and took the worms back to the farm.</td>
<td>What's going on with the boy and the worm?</td>
</tr>
<tr>
<td>8</td>
<td>The girl is passing the boy the car.</td>
<td>The girl has a car to play with. She like it a lot.</td>
<td>She went to the playground with her car.</td>
<td>What's going on with the girl and the car?</td>
</tr>
<tr>
<td>9</td>
<td>The mom is offering the baby the milk.</td>
<td>The mom bought a lot of milk from the store.</td>
<td>She put some milk into the bottle.</td>
<td>What's going on with the mom and the milk?</td>
</tr>
<tr>
<td>10</td>
<td>Jane is handing Peter the shoe.</td>
<td>Jane is going to a soccer game. She has a pair of great soccer shoes.</td>
<td>She meets Peter, who is curious about her shoes.</td>
<td>What's going on with Jane and the shoe?</td>
</tr>
<tr>
<td></td>
<td><strong>The boy is giving the snowman the scarf.</strong></td>
<td><strong>The boy is playing in the snow. He has a scarf to keep him warm.</strong></td>
<td><strong>He runs into the snowman, who feels very cold and needs a scarf.</strong></td>
<td><strong>What's going on with the boy and the scarf?</strong></td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>11</td>
<td><strong>The alligator is sending the elephant a violin.</strong></td>
<td><strong>The alligator can play the violin very well.</strong></td>
<td><strong>He is very proud of his violin, which is very expensive.</strong></td>
<td><strong>What's going on with the alligator and the violin.</strong></td>
</tr>
<tr>
<td>12</td>
<td><strong>The mom is offering the baby the scarf.</strong></td>
<td><strong>The mom bought a scarf from a department store on a cold winter day.</strong></td>
<td><strong>She brought the scarf back home.</strong></td>
<td><strong>What's going on with the mom and the scarf?</strong></td>
</tr>
<tr>
<td>13</td>
<td><strong>The zookeeper is giving the seal the fish.</strong></td>
<td><strong>The man likes fishing. He caught a fish on a cold winter day.</strong></td>
<td><strong>He brought the fish to the zoo.</strong></td>
<td><strong>What's going on with the zookeeper and the fish?</strong></td>
</tr>
<tr>
<td>14</td>
<td><strong>The boy is showing the duck the pacifier.</strong></td>
<td><strong>The boy is wandering around with a pacifier in his mouth.</strong></td>
<td><strong>He is playing by the lake, with the pacifier in his hand.</strong></td>
<td><strong>What's going on with the boy and the pacifier?</strong></td>
</tr>
<tr>
<td>15</td>
<td><strong>Mary is lending Tommy the skates.</strong></td>
<td><strong>The girl likes skating. She has a pair of great skates.</strong></td>
<td><strong>She took off her skates.</strong></td>
<td><strong>What's going on with the girl and the skates?</strong></td>
</tr>
</tbody>
</table>
### The pronoun recipient condition

<table>
<thead>
<tr>
<th>#</th>
<th>Target sentence</th>
<th>Recipient-given</th>
<th>Target picture</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>The policeman is passing the soldier the hat.</em></td>
<td>The soldier is very upset because he lost something in the street.</td>
<td>The policeman has been able to help him.</td>
<td>What's going on with the policeman and him?</td>
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<tr>
<td>2</td>
<td><em>The cowboy is sending the sailor the book.</em></td>
<td>The sailor wants to read about Asia because he will be sailing to Asia soon.</td>
<td>He came to the cowboy for help.</td>
<td>What's going on with the cowboy and him?</td>
</tr>
<tr>
<td>3</td>
<td><em>The cowboy is handing the monk an apple.</em></td>
<td>The monk is hungry, so he went to the market to buy some food.</td>
<td>He saw the cowboy with a lot of good stuff.</td>
<td>What's going on with the cowboy and him?</td>
</tr>
<tr>
<td>4</td>
<td><em>The policeman is sending the boxer a cake.</em></td>
<td>The boxer is 25 years old today. He practices every day—even on his birthday.</td>
<td>His friend, the policeman, came to celebrate his birthday.</td>
<td>What's going on with the policeman and him?</td>
</tr>
<tr>
<td>5</td>
<td><em>The nun is handing the doctor the jug.</em></td>
<td>The doctor's office is on fire. He is running out to get some help.</td>
<td>He ran into the nun, and ask her for help.</td>
<td>What's going on with the nun and him?</td>
</tr>
<tr>
<td>6</td>
<td><em>Cindy is showing Paul the picture.</em></td>
<td>Cindy and Paul are good friends.</td>
<td>They came to his home to play.</td>
<td>What's going on with Cindy and him?</td>
</tr>
<tr>
<td>7</td>
<td><em>The boy is offering the hen the worm.</em></td>
<td>The hen lays a lot of eggs everyday. The boy is collecting eggs from her.</td>
<td>The boy also helps to feed her and loves to play with her.</td>
<td>What's going on with the boy and her?</td>
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<td>8</td>
<td><em>The girl is passing the boy the car.</em></td>
<td>The boy is sitting on the ground. He doesn't have anything to play with.</td>
<td>The girl comes to play with him.</td>
<td>What's going on with the girl and him?</td>
</tr>
<tr>
<td>9</td>
<td><em>The mom is offering the baby the milk.</em></td>
<td>The baby is only 12 months old, and he is crawling in this picture.</td>
<td>The baby's mom loves him a lot.</td>
<td>What's going on with the mom and him?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Jane is handing Peter the shoe.</td>
<td>Peter loves sports. He is running around in this picture.</td>
<td>He runs into Jane, who just finished a soccer game.</td>
<td>What's going on with Jane and him?</td>
</tr>
<tr>
<td>11</td>
<td>The boy is giving the snowman the scarf.</td>
<td>The snowman is standing in the snow. He feels really cold.</td>
<td>The boy comes to play with the him.</td>
<td>What's going on with the boy and him?</td>
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<td>His friend, the alligator, runs into the room to play with him.</td>
<td>What's going on with the alligator and the him?</td>
</tr>
<tr>
<td>13</td>
<td>The mom is offering the baby the scarf.</td>
<td>It's cold outside. The mom and the baby are looking out of the window.</td>
<td>He wants to go outside and play.</td>
<td>What's going on with the mom and him?</td>
</tr>
<tr>
<td>14</td>
<td>The zookeeper is giving the seal the fish.</td>
<td>The seal lives happily in the zoo. He likes to play with children.</td>
<td>The zookeeper takes good care of him.</td>
<td>What's going on with the zookeeper and him?</td>
</tr>
<tr>
<td>15</td>
<td>The boy is showing the duck the pacifier.</td>
<td>The duck lives by the lake. She is not friendly to others.</td>
<td>The boy tries to play with her.</td>
<td>What's going on with the boy and her?</td>
</tr>
<tr>
<td>16</td>
<td>The girl is lending Tommy the skates.</td>
<td>Tommy fell off his scooter.</td>
<td>He is not hurt, but his scooter is broken.</td>
<td>What's going on with the girl and him?</td>
</tr>
</tbody>
</table>
## Appendix M

Correlation analysis results in Experiment 2.2

<table>
<thead>
<tr>
<th></th>
<th>DO% in Exp. 1.1</th>
<th>Category probe span</th>
<th>Phono. Composite score</th>
<th>Sentence STM d'</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO% Baseline</td>
<td>Pearson Correlation</td>
<td>.519</td>
<td>.576</td>
<td>.362</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.152</td>
<td>.081</td>
<td>.304</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>DO% (Pron.-Baseline)</td>
<td>Pearson Correlation</td>
<td>-.013</td>
<td>.056</td>
<td>-.410</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.974</td>
<td>.878</td>
<td>.240</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>DO% (Recipient-Baseline)</td>
<td>Pearson Correlation</td>
<td>.904**</td>
<td>.161</td>
<td>.632*</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.001</td>
<td>.657</td>
<td>.050</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>PD% (Theme-Baseline)</td>
<td>Pearson Correlation</td>
<td>-.318</td>
<td>.296</td>
<td>-.089</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.405</td>
<td>.406</td>
<td>.807</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>9</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).