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Dissertation

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The functioning of structural priming in Czech

Fungovanie štrukturálneho primingu v češtine

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I hereby declare that I have written this dissertation independently, using only the mentioned and duly cited sources and literature, and that the work has not been used in another university study programme or to obtain the same or another academic title.

In Prague on June 24th, 2024 Mgr. Maroš Filip v.r.

Abstract

Structural (or syntactic) priming is an effect in which exposure to a particular syntactic structure facilitates processing of a subsequent structure that has the same structure. This effect is observed in comprehension - we process a sentence more quickly if we have previously heard a sentence with the same structure - and in production - we are more likely to produce a sentence with a structure we have recently perceived. The syntactic priming effect is used in research to help us understand psycholinguistic questions about how our brains process language. But it is also used in studies that address linguistic questions about the representational structure of language, and is thus an important phenomenon that bridges several areas of research.

The primary aim of this dissertation was to replicate the results of structural priming in Czech. Most of the research in this area has been conducted in English, but other languages have also been included to some extent. However, this study is the first to confirm the priming effect in Czech.

This thesis presents 6 experiments focusing on different aspects of structural priming. The influence of working memory, social interaction, as well as the enhancing effects of levels of language other than syntax (repetition of lexical and morphological units) are described. In particular, this work focuses on the supporting effect of case-marking morphemes of nouns. Probably the most important finding is that the repetition of case-marking morphemes between 2 primed sentences can increase the priming effect. This finding suggests that the morphological and structural levels of language do not operate in isolation but may interact, at least to some extent. The limitations of the results and their further implications are discussed in detail in the text.

Key words:

inflectional morphology, speech production, structural priming, syntax

Abstrakt

Štrukturálny (alebo syntaktický) priming je efekt kedy vystavenie konkrétnej syntaktickej štruktúre uľahčuje spracovanie nasledujúcej štruktúry ktorá s ňou zdieľa syntax. Tento efekt je pozorovaný v porozumení – rýchlejšie spracujeme vetu ak sme pred ňou počuli vetu s rovnakou štruktúrou, rovnako aj v produkcii – s väčšou pravdepodobnosťou vyprodukujeme vetu so štruktúrou, ktorú sme pred nedávnom vnímali. Efekt syntaktického primingu sa využíva vo výskumoch, ktoré nám pomáhajú porozumieť psycholingvistickým otázkam ktoré hľadajú odpoveď na to ako náš mozog spracováva jazyk. Efekt ale nachádza uplatnenie aj v štúdiách, ktoré sa venujú lingvistickým otázkam o reprezentačnej štruktúre jazyka a je teda dôležitým fenoménom, ktorý prepája viaceré oblasti výskumu.

Primárnym cieľom dizertačnej práce bolo replikovať výsledky štrukturálneho primingu v češtine. Väčšina výskumov v tejto oblasti dosiaľ prebiehala v anglickom jazyku, do určitej miery sú však vo výskume zastúpené aj iné jazyky. Táto práca je ale prvá, ktorá potvrdila efekt primingu aj v českom jazyku.

V práci je predstavených 6 experimentov, ktoré sa sústredili na rozličné aspekty štrukturálneho primingu. Opísaný je vplyv pracovnej pamäte, sociálnej interakcie, ale aj podporných vplyvov iných úrovní jazyka než štruktúry (opakovanie lexikálnych a morfologických jednotiek). Práca sa zameriava predovšetkým na podporný efekt flektívnych morfém podstatných mien. Zrejme najvýznamnejšie zistenie práce je, že opakovanie koncových morfém podstatných mien medzi 2 primovanými vetami môže zvýšiť primingový efekt. Tento výsledok naznačuje, že morfologická a štrukturálna úroveň jazyka nefungujú izolovane, ale môžu sa minimálne do určitej miery ovplyvňovať. V práci sú podrobne rozpísané obmedzenia zistených výsledkov a ich ďalšie implikácie.

Kľúčové slová:

flektívna morfológia, produkcia reči, syntax, štrukturálny priming

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List of acronyms

ABS - absolutive

ACC – accusative

A/D – accusative/dative

D/A – dative/accusative

DAT – dative

DO – double-object

EEG – electroencephalography

ERG - ergative

ERP – event-related potential

FPS - functional sentence perspective

GLMM – generalized linear mixed-effect models

L1 – first language

L2 – second language

MC – main clause

NOM - nominative

NP - nominal phrase

OVS – object-verb-subject

PO – prepositional object

PP – prepositional phrase

RC – relative clause

RR – reduced relative clause

RSVP – rapid serial visual presentation

RT – reaction time

SLI - specific language impairment

SVO – subject-verb-object

V - verb

WM – working memory

1. Introduction

As Chomsky (1975) pointed out, a person can create and understand an infinite number of grammatically correct sentences in his native language that he has never heard before. However, the limitation of cognition lies in opposition to these creative possibilities, as can be seen in the tendency to repeat words or sentence structures. Repetition is easier for the brain than inventing new ways of formulating expressions, and moreover, people have only a limited number of words or structures available to express a particular idea.

Repetition is a general ability of the cognitive system that manifests itself in learning or imitation behavior. For example, the repetition of previously perceived linguistic material can be explained by priming, which is the term used for many distantly related effects. It is commonly used to describe an effect in which exposure to a stimulus (*prime*) implicitly influences the response to a subsequent stimulus of the same type (*target*). The priming effect is usually temporary, and people try to correct for it when they become aware of its influence (Janiszewski and Wyer, 2014). A typical example might be *content priming*, where, for example, after buying a new red car, its owner now sees red cars everywhere. When people are exposed to a stimulus, the priming effect influences the processing of the stimulus and makes the operations responsible for its processing more available. In general, there are two types of priming. When the processing of the subsequent stimulus increases, this is called *positive priming*, and when the processing slows down or the stimulus is ignored, this is referred to as *negative priming.*

In the linguistic domain, priming is studied at two levels – the lexical and the structural. In *lexical priming* the prime word enhances the processing of the subsequent target word if they are connected at the phonological or semantic level (sometimes called *semantic priming*). In *structural priming*, target sentences are understood or produced more quickly because they share some structural features (e.g., syntax) with the initial sentences. The following section features a discussion of the history of priming studies in linguistics.

1.1 Beginning of priming studies in linguistics

The first authors to demonstrate lexical priming were Meyer & Schvaneveldt (1971), who in a lexical decision study measured the response times to different words. The research consisted of presenting words and nonwords on a single layer, i.e., one string of letters displayed on the other. Participants had to decide whether the stimuli represented two words, two pseudowords, or a combination of the two. The results showed that responses were faster when the two words were commonly associated, i.e., the word *doctor* was processed faster if the other word was *nurse* rather than the word *bread*. This repetition can be explained by widespread activation in the neural structure of the brain (Reisberg, 2007). When the prime word is activated, the words that are connected to it through associative networks are also stimulated, increasing the likelihood that they will be activated next.

After observing lexical priming, the question began to arise as to whether a similar repetition effect might exist at the structural level. Probably the first notion of syntactic repetition came from Schenkein (1980, as cited in Branigan, 2007), who in a language analysis of two robbers, noticed that 'resources', including syntax, were repeated one after the other. A conversational study conducted by Weiner & Labov (1983) also found that people tend to use the passive construction if they have used it recently.

Further research focusing on the repetition of syntactic forms was conducted by Levelt & Kelter (1982). In their experiment, they focused on the repetition of sentence forms with and without a prepositional phrase. In a question-and-answer dialogue, they asked several hundred merchants one of the Dutch equivalents of the sentences *At what time does your shop close?* or *What time does your shop close?* They received answers mostly in two forms; the first question, which contained a prepositional phrase, tended to be answered in a complementary form *At five o'clock*, and the second question was answered mostly with the sentence *Five o'clock*. Since the experiment concerned the repetition of a prepositional form, it was unclear to what extent the lexical priming given by the repetition of the preposition was responsible for this effect, and to what extent the forms of the syntactic structure of the prepositional phrase were responsible for the repetition. Lexical repetition may have played a role in each of the previously mentioned studies, which means that Bock's research (1986) was the first to deal directly with structural priming.

1.2 Bock's first study of structural priming

Bock (1986) examined the tendency to use the same structure in several consecutive sentences. The experiment consisted of presenting priming sentences that participants repeated verbally, followed by a description of a semantically unrelated picture. The sentence describing the picture served as the target sentence and was expected to have the same syntactic structure as the priming sentence. The increase in the use of a particular syntactic structure, if that structure appeared earlier, was explained by neuronal activation and the strengthening of information. This activation positively affects subsequent cognitive processes, in this case speech production.

Bock demonstrated this phenomenon on two syntactic structures. In the first case, priming sentences were presented in either active (*One of the fans punched the referee*) or passive form (*The referee was punched by one of the fans*). The target sentence produced by the image description could be uttered in either of these forms. The results showed an increased tendency to use the passive voice after hearing the passive sentence and the active structure after hearing the active priming sentence (in both cases by 8% compared to the opposite structure). Bock then investigated the effect of syntactic priming on double-object dative constructions (*The secretary is baking her boss a cake)* and prepositional dative constructions (*The secretary is baking a cake for her boss*). The findings were the same; double-object priming sentences increased the probability of describing the picture with double-object structures, and prepositional dative sentences increased the probability of prepositional dative structures (both by approximately 22% compared to the opposite structure).

In contrast to previous research, Bock confirmed the repetition of syntactic forms of sentences in successive expressions even without their connection to the lexical level. Although the preposition *by* was repeated across passives and the preposition *to* was repeated across prepositional datives, there was no repetition of structural markers in the actives and double object datives.

1.3 Structural priming as a cognitive phenomenon and research method

Syntactic priming, or as Bock (1986) called it, syntactic persistence, is the phenomenon in which the processing of a sentence with a particular structure facilitates the processing of a subsequent sentence with the same or similar structure. Since the first study, this has been confirmed in language comprehension and production in

written and spoken form (for the review, see Pickering and Ferreira, 2008 or Tooley and Traxler, 2010) and cross-linguistically (Loebell & Bock, 2003). Priming has been studied in many different languages (e.g., English – Bock, 1986; Dutch – Hartsuiker and Kolk, 1998; Basque – Santesteban et al., 2015, or Mandarin – Chen et al., 2019; for review see Pickering and Ferreira, 2008; Branigan and Pickering, 2017) on many different structures and with a large number of methods (see Chapter 2).

The widespread popularity and utility of structural priming lies in the fact that it is not only a cognitive repetition phenomenon, but an important research technique that can be used to study both the representations and the processes at the clausal and sentential levels (Branigan & Pickering, 2017; Feng et al., 2014). It can link questions addressed in psycholinguistics with those examined in theoretical linguistics. This is possible because priming seems to be sensitive to abstract representational categories.

For example, based on priming tendencies, Pickering and his colleagues (2002) concluded that constituent structure is formulated in one stage rather than in multiple stages. According to the multiple stage model, called dominance-only account, constituent structure formation is comprised of two stages. In the first stage, only a representation of hierarchical (or dominance) aspects between constituents is created. This level computes which phrase node is dominant, but not their order. This is done in the second stage when this information is converted into a second representation based on the order of the constituents. On the other hand, the single-stage model only predicts the linearization without going through the dominance stage. Pickering and his colleagues examined three types of dative transitive sentences – a prepositional object sentence (PO, sentence 1), a double-object sentence (DO, sentence 2), and a shifted sentence (sentence 3). The shifted type of dative sentence is relatively rare, but it is still acceptable.

1. The racing driver showed the extremely dirty and badly torn overall to the mechanic. (PO)
2. The racing driver showed the mechanic the extremely dirty and badly torn overall. (DO)
3. The racing driver showed to the mechanic the extremely dirty and badly torn overall. (shifted)

Each of these sentences has a different constituent structure. PO has a V-NP-PP structure, DO has a V-NP-NP structure and shifted has a V-PP-NP structure. However, there should be no difference in the first stage of the multilevel *dominance-only account* between PO and shifted sentences. The difference between the two is only found in the order of the constituents, which should not be computed in the first stage. Since priming appears to be sensitive to the representational levels, when PO and shifted sentences prime each other, this should be evidence of the multiple-stage model. However, the results showed the opposite; PO and shifted primes produced significantly different proportions of PO targets, suggesting that the representation of the constituent is computed in a single stage.

Until the discovery of the syntactic priming effect, it was difficult to study these syntactic operations in isolation. Previously used methods relied on acceptability judgments, speech errors analysis, or similar approaches and could only yield limited conclusions about syntactic production (Branigan & Pickering, 2017). Judging acceptability is highly subjective, but it should not be a problem when ratings from a large group of participants are collected. However, all participants may make the same or similar assessment errors based on cognition. People tend to judge more frequently repeated sentences as more acceptable, have a different idea of what *grammatical* means, or are subject to many different cognitive fallacies, e.g., evaluating the garden-path sentences as ungrammatical. The discovery of structural priming thus allows not only the examination of the process of language production, but the study of the structural representation of language.

The next chapter will describe how structural priming is studied and which structures are associated with it. The following sections will then discuss priming in different populations and how structural priming uncovers syntactic and structural relations. Throughout the work, a distinction is made between language production and language comprehension. Since priming has been studied more in production, when comprehension is not explicitly mentioned, the text refers to priming in production.

2. Structural priming in research

2.1 Structures used in production studies

When structural priming expresses the tendency to repeat the structural form of two otherwise unrelated sentences, it signals that the two sentences are similar in some way at the structural level. However, this brings a limitation to the study of priming, namely that one can only study sentences that have roughly synonymous but structurally different counterparts. If an image in the image description task has only one acceptable syntax for description, i.e., in a situation where there is no variation, it will not be possible to tell whether participants chose a particular structure because of the priming effect, as they are forced to do so because they had no other choice. This is also true for other experimental paradigms.

Branigan & Pickering (2017) mention another problem, namely the situation where an alternative structure is rare. This can be a problem if the participant finds the alternative ungrammatical or odd in some way (e.g., an unnatural information structure without context).

The infrequency or rarity of a structure is linked to the *inverse preference effect*. The inverse preference effect is a general cognitive phenomenon in which cognition focuses on less standard stimuli (e.g., the mind is better at remembering strange memories than common ones). In structural priming, it manifests itself in less common structure being more likely to be primed than its more common counterpart (with the one exception noted above, when the structure is found to be strongly ungrammatical or unaccepted). The inverse preference effect in priming has been confirmed by many studies (e.g., Hartsuiker & Kolk, 1998; Scheepers, 2003; Wei et al., 2022).

Some sentence structures are more suitable for priming studies because they have a good counterpart or alternation that is commonly used. The two syntactic alternations used by Bock (1986): voice alternation (active/passive) and transitive dative sentences (PO/DO) is a good example. Other studied structures on which structural priming was confirmed focused on the position of the phrasal verb and the particle (A celebrity threw in the first ball/The celebrity threw the first ball in; Konopka and Bock, 2009), the production or omission of the complementizer *that* (The mechanic mentioned that the car could use a tune-up/ The mechanic mentioned the car could use a tune-up; Ferreira, 2003). In some cases, instead of whole sentences, complex noun-

phrase forms were used – adjective and noun vs. noun and relative clause (the red sheep/the sheep that is red, Cleland & Pickering, 2003).

At times, in languages other than English, the situations are different and even easier because more structures can be used in research. It all depends on the morphological typology of the language. English is mostly described as an analytic language; it uses word order and auxiliaries to convey meaning. Other morphological classes do not depend on a strict word order because they use affixes to express meaning. Fusional languages depend on inflections (e.g., Russian, Czech, Spanish, and German) and agglutinative languages use agglutination – chaining different semantic morphemes together (e.g. Turkish, Hungarian, and Japanese). It is true that a language cannot be strictly assigned to one morphological typology class; most languages can be assigned to more than one morphological category or they lie on the border of two categories. However, the abovementioned languages have greater freedom in their word order.

In German, priming has been found for high vs. low attachments of relative clauses (NP-of-NP-RC structures; Scheepers, 2003). The following sentence contains a good example: "Don mentioned the servant of the actress who was on the balcony", where the RC *on the balcony* can refer to either the *servant* or the *actress*. This ambiguity could be resolved in German by using nouns with different genders, where the obligatorily used German article is informative about the gender and hence about the object of the RT binding. As a result, this sentence could be used as an unambiguous prime.

Many studies were also done in Dutch, which belongs to Germanic language family; however, it is more fusional than English. The used structures included the alternation of locative phrases (on the table is ball/a ball is on the table; Hartsuiker et al., 1999), and the order of the past participle and the auxiliary at the end of the clause, which in Dutch is grammatical (The man called the police, because his wallet was stolen /The man called the police, because his wallet stolen was*; Hartsuiker & Westenberg, 2000).

2.2 Paradigms in production studies

The next section examines the tasks used to study structural priming. In all of the following paradigms, at least some priming effect has been detected.

2.2.1 Picture description task

The first paradigm used by Bock in her pioneering study (1986) was the picture description paradigm. Research materials in this paradigm consist of pairs of prime sentences and target pictures that participants should describe. The target picture could be described with the same syntax as the prime sentences or its alternation, e.g., as a PO or DO dative structure. In one condition, the image is preceded by one type of syntax and in the other condition by an alternative syntax, usually accompanied by a third condition where the image is combined with a "neutral" syntax to determine what structure is preferred when one is not primed. Filler items are included between the prime-target pairs. The study participants read the sentences and describe the following pictures while the session is recorded. When syntax is repeated between utterances, this indicates structural priming.

This task is mostly disguised as a memory test. The participants are asked to learn a set of pictures and sentences in the first learning phase, while learning stimuli serve as fillers that are then repeated in the second part. In the second phase, participants are shown a sequence of sentences and pictures, with some of the stimuli being new (prime-target pairs) and some repeated from the learning phase (fillers). The goal is to describe the picture or read the sentence aloud and then say whether the stimulus is new or not.

This paradigm has been used in a variety of priming studies under laboratory conditions (Bock, 1986; Bock and Loebell, 1990) or online (Ziegler et al., 2019). It sometimes includes minor variations. For example, sometimes the participants repeat the sentences aloud in the learning phase, or items are switched by the participant or experimenter in the second phase. Vernice and her colleagues (2012) altered this paradigm somewhat more when they tested the priming of emphasis independent of syntactic repetition. The participants first silently read the sentences containing the clefts, then decided whether the picture matched the sentence, and then first described the target (or filler) pictures.

The picture description task is mostly used in response tendency studies, where the frequency of produced target structures is examined. However, this paradigm was also used in reaction time (RT) studies, where the RT of target sentences that should be shorter in primed condition is examined (Segaert et al., 2011).

2.2.2 Dialogue game

Branigan, Pickering and Cleland (2000) used the picture description paradigm in an interlocutor setting to study priming in dialogue. In this confederate scripting paradigm, a real participant and a researcher's confederate describe pictures to each other. One of the partners describe a picture and the other has to find the matching picture among a set of cards. The pretended goal of the experiment is to understand communication in an environment in which people cannot see each other.

Participants have two sets of pictures on the table in front of them, but they cannot see each other. One set contains pictures that the participant has to describe to the confederate, and the second set contains pictures that the participant has to match to the description of the confederate. The set of descriptions also includes filler pictures, and the set of selections includes one distractor card for each verb. The participants take turns in describing and are instructed not to talk at another time. The confederate has a script for how to describe the cards. The confederate is first to describe the card, which allows the priming of the participant's description. This method has also been used to address cross-linguistic priming by Schoot and her colleagues (2019) and Hartsuiker and his colleagues (2004).

2.2.3 Sentence completion paradigm

In this paradigm, the participants are presented with sentence fragments that they should complete. This task has been used in both written (Pickering & Branigan, 1998; Hartsuiker & Westenberg, 2000) and oral forms (Hartsuiker & Westenberg, 2000). Participants are either given booklets with sentence fragments to complete in writing, or they are instructed to complete the presented sentences orally while their sentences are recorded. Sentence fragments that serve as targets can be finished by at least two different structures and are preceded by sentence fragments that serve as primes and consist of the structures that may be repeated in the following target sentence. No matter how the prime sentence is completed, it already consists of a structure that primes the following utterance or cannot be completed in any other way. Examples of primes include PO/DO constructions *The racing driver showed the torn overall… / The racing driver showed the helpful mechanic…*, with a following target fragment that can be finished either way *The patient showed…* This method was used to

study not only probability of structure repetition but the latency of typed responses (Corley & Scheepers, 2002; Segaert et al., 2011).

2.2.4 Other paradigms

Potter and Lombardi (1998) did not study structural priming in the situation of creating a new target sentence but in recall settings. Participants first saw the target sentence and then the prime sentence. They task was to recall first the prime sentence and then the target sentence. The target sentence can be expressed in two ways. Potter and Lombardi postulate that immediate recall involves the recall of the surface structure and hence the type of prime sentence should affect the syntax of the recalling target. They used rapid serial visual presentation (RSVP) where the words are presented one after another within 100 ms.

Smith and Wheeldon used the moving picture description methodology in a series of online experiments to study the RT effects of structural priming (Smith and Wheeldon, 2001; Wheeldon and Smith, 2003; Wheeldon, Smith and Apperly, 2011). This is similar to picture description task; however, the participants do not see alternating priming sentences and target pictures, only pictures. Each picture contains two simple objects that are moving in the same direction (e.g. the spoon and the car move up) or in different directions (e.g. the eye moves up and the fish moves down). In a syntactically related condition, the prime and target matching have the complexity of the internal structure (e.g., both used conjoined noun phrase: the eye and the fish move apart/ the spoon and the car move up), but not in the syntactically unrelated condition, where priming is not expected (the eye moves up and the fish moves down/ the spoon and the car move up).

2.3 Structures and paradigms in comprehension studies

The situation is different for language comprehension. During production the researchers observe whether one syntax will facilitate the production of other – which could only be considered as successful priming if an alternative syntax could be chosen. Production studies feature the use of structures that are syntactically synonymous (e.g. PO and DO ditransitive sentences). In comprehension studies, alternative constructions are not used for primes and targets; instead, the same structures with a temporal syntactic ambiguity that makes them sound different when first perceived are used. In

comprehension studies, the accuracy or reaction time of the comprehension is measured.

A good example is found in ambiguous or garden path sentences which first appear to have a different structure (they lead parsing to a wrong path), but when participants come to comprehend a certain word in a sentence which does not fit their parsing, they are forced to find a new meaning and syntax for the sentence to make sense (e.g. *The guys chased the dogs and the cats in the attic watched rats*). When participants go over the same confusing structure again, they should be able to read it correctly and avoid going down the garden path, because they are already primed for the correct parsing. A similar example is found in sentences that are difficult to understand because of their unusual syntax. These sentences should be easier and faster to understand on a second encounter due to the effect of structural priming. The effect could be measured by an eye tracker or an electroencephalogram (EEG).

2.3.1 Eye tracking studies

An eye tracker is a device that monitors eye movements. When readers encounter a syntactically incorrect word in a garden-path or ambiguous sentence, they tend to reread the sentence in order to parse it in a new way and incorporate the "improper" word into the syntactic structure. The study compares reaction times, or gaze and its shifts in situations where ambiguous sentences are primed and not primed.

Pickering and Traxler (2004, in Ledoux et al., 2007) conducted such an eye-tracking study in which they found the effect of structural priming on reading times. RTs were shorter when the reduced relative clause (RR) target (*The defendant examined by the lawyer was unreliable*) was preceded by an RR sentence than by the main clause (MC) prime sentence (e.g., *The defendant examined the evidence*). In this example, the past participle *examined* in RR is not explained as a past participle but incorrectly as the past tense of the subject *defendant* and thus as an MC structure. When participants encounter the phrase *by the lawyer*, this explanation must be abandoned and changed to the RR. However, this structural priming effect was observed only when the verb was repeated across sentences.

2.3.2 EEG studies

An electroencephalograph (EEG) is a machine that measures the electrical activity of the brain from the scalp. More precisely, experiments use event-related potentials (ERPs), which are waves time locked to a concrete stimulus (e.g., presentation of an ambiguous word) and averaged over many trials to filter out noise signals. There are two important language ERP components. N400 component is a negative deflection that peaks around 400 ms after the presentation of the stimulus and reflects the difficulty of semantic lexical processing. P600, a positive going wave with a peak of around 600 ms after stimulus, is sensitive to syntactic anomalies or difficulties in grammatical processing.

Ledoux and his colleagues (2007) conducted an experiment similar to Pickering and Traxler's eye tracking experiment (2004, in Ledoux et al., 2007; see previous section) but they measured ERP components. The targets were always RR sentences (*The manager proposed by the directors was a bitter old man*) preceded by another RR structure or MC structure (*The speaker proposed the solution to the group at the space program*). The verb was always repeated between them. RR sentences are more difficult to process, but after MC primes they found greater positivity following the critical noun than in RR primes that resembled deflection in the P600 component found in other studies. Although this suggests priming, their analysis did not confirm that lexical repetition was needed for structural priming in comprehension.

2.3.3 Expression-picture matching task

Branigan, Pickering, and McLean (2005) used a different paradigm that did not involve technical devices like the studies above, but resembled priming studies in production in the way it measured response tendencies. They examined the processing of prepositional phrases (PP) which can have both high and low attachment. For example, in the expression *The waitress prodding the clown with umbrella*, the object umbrella can be attached either to the waitress (high attachment) or to the clown (low attachment). Participants first read an ambiguous prime expression and then had to choose from two pictures the one which corresponded to the sentence. In prime condition, only one picture corresponded, thus disambiguating the syntax. In the following target item, the participant read a similar ambiguous expression but saw two pictures where both fit the sentence, one as a low PP attachment and the other as a high

PP attachment. The participants chose more of the same attachments after hearing the same one, thus demonstrating the effect of structural priming on sentence interpretation, but not in situations when the verb was not repeated.

2.4 Structural priming in specific populations

Priming can enrich the knowledge of syntax processing but not only through the study of healthy adult population. Studies on children can reveal how syntax processing develops and changes with age. It can help to understand which mechanisms are impaired in a population with language disorders (such as people with aphasia or children with specific language impairment - SLI) and thus help to develop more appropriate treatment. The different effects of priming in clinical populations, e.g., in people with aphasia, compared to healthy populations, could also shed light on the functioning of priming, while studies in bilingual speakers can untangle how syntax in L1 and L2 are linked and how they may influence each other. The next section features a presentation of research from these areas.

2.4.1 Structural priming in children

Structural priming has proven to be a helpful tool in addressing the question of which syntactic entities are represented in children and how syntactic knowledge is developed.

Savage and her colleagues (2003) were interested in the question of the extent of the abstractness of children's syntactic representations. They tested 3-, 4-, and 6- year-old children with active and passive structures. The task was to repeat the prime sentence after the experimenter and then to describe the target picture. Half of the children were presented with prime sentences that lexically overlapped with possible target descriptions, and the other half were presented with prime sentences with impossible lexical overlaps. Older children (6 years) showed abstract structural priming as well as lexical priming, but younger children (3 and 4 years) showed priming only where primes and targets overlapped lexically (pronoun *it*, e.g., target: *It pushed it*; prime: *It cut it.*). This would suggest that among the older children syntax is represented in abstract form, but in preschoolers it is still in development and represented, at least partially, by lexical items (e.g., pronouns) or grammatical morphemes.

This result contradicts other studies that observed a priming effect in younger children without a lexical boost. One of the first such studies was conducted by Huttenlocher et al. (2004). They observed priming without lexical repetition in 4- and 5-year-old children using actives/passives, and PO/DO dative structures, similar to typical experiments with adults (e.g., Bock, 1986). The same results were obtained by Shimpi et al. (2007), who again used a picture description paradigm with the same types of structures as in a previous study by Huttenlocher et al. (2004). They confirmed the priming effect in 4-year-old children. However, they also included 3-year-olds in whom they did not observe a priming effect when the task was to listen to primes and then describe the targets. When 3-year-olds were asked to first repeat the prime sentence and then describe the target, they found a significant effect. This suggests that younger children also store abstract syntactic representations, but its access is likely to depend on the task.

Many later studies have replicated these findings (e.g. Messenger et al., 2012a; Kidd, 2012) or expanded them to new conditions. The priming effect has also been found in a corpus study (2 – 7.5 year old children; Jeffrey et al., 2010), in languages other than English (Spanish – Gámez et al., 2009; Japanese – Arai and Mazuka, 2014). Messenger and her colleagues (2012b) tested younger (6-year-olds) and older children (9-year-olds) and found that both groups could be primed by constituent structure, but that the younger children repeated the constituent structure in their passive target descriptions, but reversed the thematic role structure. This suggests that 6-year-olds have already mastered the constituent structure of passives, but, unlike 9-year-olds, have not yet mastered the proper mapping of thematic roles.

Bencini and Valian (2008) replicated abstract structural priming in 3-year-olds, but also controlled for animacy, showing that the priming effect is not due to animacy. Although priming occurs even without repetition of animacy, Gámez and Vasilyeva (2015) found that animacy can enhance the priming effect in children (5- and 6-year-olds). Thothathiri and Snedeker (2007) used an eye-tracking experiment to demonstrate a priming effect in comprehension in both 4-year-old and 3-year-old children. There was also no significant difference in priming between children with SLI and typically developing children (Miller and Deevy, 2006), and no difference in the lexical boost effect between the two populations (Foltz et al., 2015).

Overall, the studies show that children use abstract structural representations in language production and comprehension, and that the priming effect increases with age. However, as Kidd (2012) pointed out, there is a great deal of variability in the priming effect in children across experiments. Other cognitive abilities, such as language proficiency (Kumarage et al., 2022) or working memory (Foltz et al., 2015), also appear to be an interindividual factor that may influence priming tendencies in children. This not only suggests large interindividual differences in priming effects in children, but also points to the fact that different children may have developed different levels of abstract syntactic representation at the same age.

2.4.2 Structural priming in bilinguals

The first study to test the hypothesis that structural priming can occur across languages was done by Loebell and Bock (2003). Although the research was conducted in 1990, the pioneers of structural priming had to wait 15 years for structural priming to become more accepted before they could publish this at the time far-fetched idea that structures can be primed across languages (Loebell & Bock, 2013).

In their research, Loebell and Bock (2003) tested whether structural priming would occur between German and English and vice versa. Different languages naturally use different grammars, but some constructions are the same, which is even more true if they belong to the same language family. Loebell and Bock hypothesized that dative sentences (PO/DO) will lead to priming (Sentences 1 and 2) because they share syntactic structure between the languages. However, they made the opposite prediction for passive/active sentences (Sentences 3 and 4) because their structure configuration is different and therefore, they should not prime each other. A picture description paradigm was used for the experiment. All of the participants took part in two sessions, one in which they read prime sentences in German and described pictures in English, and in the other in which the languages were swapped. All of the participants (N=49) were L1 German speakers and L2 English speakers who had lived in the US for at least 2 years.

1. DO prime in English: The lawyer sent his client the contract.
2. DO target description in German: Eine Frau zeigt einem Mann ein Kleid. (ENG: A woman shows a man a dress.)

3. Passive prime in English: The concert was attended by many people.
4. Passive target description in German: Das verängstigte Kind wurde von einem Hund gefunden. (ENG: The frightened child was found by a dog.)

The results showed that fluent speakers of German and English repeat syntactic constructions across languages and supported the hypothesis that the effect of structural priming is not limited by language. The data agreed with the proposed idea that ditransitive sentences would be primed more than active and passive sentences. Although there was a tendency for priming in active sentences which are similar across languages, there was no tendency for priming the passives, which are structurally different. The only significant priming effect was for ditransitive sentences that shared a structure configuration. This supports the idea that structural priming is dependent, at least in part, on structure configuration and does not depend on the word or meaning level and, as shown in this research, not even on the language level. This result also supports the theory that at least some stores for two different languages are shared (interactive theory) and languages are not stored completely separately in bilingual speakers (modular theory).

Similar results were then obtained by Hartsuiker, Pickering, and Veltkamp (2004), who studied cross-linguistic priming in Spanish-English bilinguals using a dialogue game paradigm, and by Bernolet, Hartsuiker, and Pickering (2007), who studied cross-linguistic priming in German-Dutch and Dutch-English bilinguals. These studies also tried to shed light on the issue of syntactic structure creation. In psycholinguistics, there are two major approaches to the creation of syntactic structure. According to the two-stage model, the constituent structure is computed in two steps – first the functional relation (dominance level) is computed and then the positional relation between the constituents (their order) is computed. According to the one-stage model, both levels are computed simultaneously in one step. Since all of the above studies found cross-linguistic priming only where word order was repeated across languages, this led the authors to assume that the one-stage model of grammatical encoding is supported by the evidence.

On the other hand, Desmet and Declrecq (2006) provided evidence in favor of the two-stage model. They did not focus on the argument about the one- or two-stage model, but tried to confirm the interactive theory of bilingual language processing.

However, their observations speak in favor of the two-stage model of grammatical encoding. In their Dutch-to-English bilingual study, they successfully primed a high-attachment relative clause from Dutch and English, even though the sentences did not share a constituent structure, namely verb position (e.g., Dutch prime: *De docent adviseerde de leerlingen van de lerares die… weren*, English translation: The lecturer advised the students of the teacher who… were; English target: *The farmer fed the calves of the cow that were…*). Since positional relations are not repeated across sentences, it is the dominance level that should be repeated and responsible for the priming effect.

A study by Shin and Christianson (2009) attempted to resolve this controversial issue of whether cross-linguistic priming is based on the functional or prepositional level by examining priming in two languages, namely Korean and English, by modulating their argument order and syntactic structure. Korean has a different word order than English (SOV vs SVO), but the structural and functional relations in dative constructions are parallel to English. In Korean there are postpositional dative constructions (PO, Sentence 5), which correspond to the English prepositional dative constructions (Sentence 6) (both have the same functional constituents: verb, noun phrase and post/prepositional phrase), and double-object datives (DO, Sentence 7), which corresponds to English DO structures (Sentence 8) (both have the same functional constituents: two noun phrases and verb).

5. Korean PO: Mary-ka (Mary-NOM) John-eykey (John-to) chayk-ul (book-ACC) cwuessta (gave).
6. English PO: Mary gave a book to John.
7. Korean DO: Mary-ka (Mary-NOM) John-ul (John-ACC) chayk-ul (book-ACC) cwuessta (gave).
8. English DO: Mary gave John a book.

What is different between languages is the argument order, which is *recipient-theme* for Korean PO and DO sentences, but in English it is shared only by DO sentences, and English PO structures have the opposite argument order *theme-recipient*. Because only Korean postpositional datives were primed to the English prepositional datives and not double object datives between languages, it supports the theory that only functional-level priming occurs.

2.4.3 Structural priming in people with aphasia

Patients with aphasia have a speech impairment after an acquired brain injury. The damage varies depending on the areas of the brain affected and the extent of the damage. As shown in a series of studies, people with aphasia are also susceptible to structural priming (e.g., Cho-Reyes & Thompson, 2012; Cho-Reyes et al., 2016), and these experiments help to understand the mechanism of priming.

Hartsuiker and Kolk (1998) found that patients with Broca's aphasia who did not spontaneously produce passive constructions could be primed to produce them. That is informative about the functioning of sentence processing in these patients. It suggests that their knowledge of passives (or potentially other complex sentences) is not erased from their language processor, but they probably just lack the computational processes to produce such complex sentences. This can be overcome by automatic facilitatory process such as priming.

Cho-Reyes and Thompson (2012) examined the duration of the priming effect in patients with aphasia, inserting 2 or 4 intervening sentences between the prime and the target. It has previously been shown that in a healthy population, the priming effect can survive 10 interfering sentences (Bock & Griffin, 2000). Cho-Reyes and Thompson's study showed that there was no difference between the control group and aphasia patients in priming effect for either two or four intervening sentences. This result indicates that the priming effect is long lasting even for people with aphasia and speaks for an implicit learning mechanism behind priming. The same results were obtained in a following experiment by Cho-Reyes and her colleagues (2016).

Yan and his colleagues (2018) found that aphasia patients with short-term memory impairment show the same lexical boost effect as control group participants, although they have difficulty retaining semantic or structural information. There was no relationship between the level of short-term memory deficit and the size of the lexical boost effect. This suggests that the lexical boost effect is not driven by explicit memory, as suggested by some theories (Chang et al., 2006; see Chapter 4 for details).

In general, priming effects are observable even in populations that are not fluent or proficient language users. However, these populations are less susceptible to priming effects than typical adults (e.g., children - Bencini and Valian, 2008; Arai and Mazuka,

2014; people with aphasia – Haarmann and Kolk, 1991; children with SLI - Leonard et al., 2000), but there are also some contrary observations (e.g., people with aphasia – Hartsuiker & Kolk, 1998).

3. Is structural priming syntactic?

There is some debate in the literature about the underlying mechanisms and representations of priming. The question is whether the effect is exclusively syntactic, or whether other linguistic entities outside syntax (e.g., thematic roles or information structure) play a role in the repetition effect. Priming is an effect in which the processing of one stimulus influences the processing of a subsequent stimulus based on the shared aspects of their representation (Branigan & Pickering, 2017). But after the repetition of the same sentences, priming can be elicited because of a shared constituent structure or repetition at a different linguistic level. For example, after reading the DO sentence *"A rock star sold some cocaine to an undercover agent"*, the enhanced production of the following DO structure ("*The old man is reading story to the boy"*) may depend on a repetition of semantic roles (patient-theme), a lexical repetition of a close class word *to,* or a repetition of prosody. Thus, researchers should determine the aspects of language repetition on which structural priming depends.

As shown in the research by Ziegler and his colleagues (2019), the effect of structural priming does not seem to be based solely on abstract syntactic structure. This chapter seeks to summarize the language effects that play a role in priming. A distinction is made between structural effects which express a certain relation or hierarchy between lexical units (constituent structure, information structure, thematic role structure), and non-structural effects which do not express relations (animacy, word repetition, prosody, and phonology).

3.1 Non-structural effects

3.1.1 Lexical boost effect

Research provides compelling evidence for the independence of structural priming from other levels of language. Structural priming has been found to occur without the repetition of a lexical items (Bock, 1986, 1989; Pickering & Branigan, 1998), but lexical repetition can enhance priming (usually involving the head of a phrase - the noun in noun phrases or the verb in verb phrases; Cleland & Pickering, 2003). This effect is called the *lexical boost* effect. These findings were observed not only in English, but

also in other languages such as Mandarin (Huang et al., 2023) or Dutch (Hartsuiker et al., 2008).

The residual activation model introduced by Pickering and Branigan (1998, discussed in detail in Chapter 4) assumes that only head constituents can boost priming. But research by Scheepers, Raffray, and Myachykov (2017) found that non-head constituents can also increase structural priming. This observation has not been confirmed by other studies (Carminati et al., 2019; Huang et al., 2023), and thus, without conclusive evidence, the question of whether non-head constituents can also cause a lexical boost effect remains open.

3.1.2 Effect of animacy

The role of animacy was observed in a study where Bock and his colleagues (1992) successfully primed the repetition of an animacy feature associated with a grammatical function (subject, object or oblique), but other studies have not confirmed this result (Bernolet et al., 2009; Tanaka, 2008). The independence of structural priming from animacy has also been confirmed in Mandarin, whose syntactic parsing seems to be more dependent on the semantic features that includes also animacy (Huang et al., 2016; Chen et al., 2020). Gámez and Vasilyeva (2015) observed the effect of animacy on structural priming in 5- to 6-year-old children. However, since children may place more emphasis on animacy cues when decoding sentence structure, this observation may not be transferable to adults, as previous studies have suggested.

3.1.3 Closed class words

Priming does not appear to be based or even enhanced by closed class words such as prepositions. Dative alternation priming occurs to the same extent independent of the use of the preposition type (Bock & Loebell, 1990).

3.1.4 Prosody and phonology

In the same study (Bock & Loebell, 1990), it was also shown that prosody did not play a role in structural priming, where the target sentence "*The girl is handing a paintbrush to the man"* was not primed by the sentence "*Susan brought a book to study"* but was primed by the prime prosodic counterpart "*Susan brought a book to Stella".* Again, this shows that the repetition of a closed class word (the preposition *to*) has no

effect. Similarly, phonology was found not to be responsible for repetition (Cleland & Pickering, 2003), as the target "*a sheep that's red"* was primed to the same extent by the phonologically-related phrase "*a ship that's red"* as by the phonologically-unrelated phrase "*a ball that's red"*.

3.2 Structural effects

The next question is whether structural effect is essentially syntactic and based on constituent structure repetition, or whether other structural levels also play a role. This is difficult to prove because the different structural levels often overlap.

3.2.1 Thematic roles

Messenger et al. (2012) showed that passives are primed regardless of thematic roles, or at least that the priming of thematic roles was overridden by syntax repetition; the participants produced agent-patient passives (*"The doctor gets licked by the cow"*) in equal amounts after experiencer-theme passives *("A mouse is being annoyed by a pirate"*) and after theme-experiencer passives ("*A pirate is being heard by a mouse*"). Similar results were obtained by Bock & Loebell (1990), where prepositional locatives (*"The wealthy widow drove the Mercedes to the church."*) primed prepositional locative structures to the same extent as prepositional dative structures (*"The wealthy widow gave the Mercedes to the church"*, but Ziegler et al. in 2019 challenged this explanation - see subsection 3.3 Conclusion).

However, Chang and his colleagues (2003) found the influence of thematic roles. In their experiment, they primed the order of thematic roles in spray-load verb sentences (example of primes: *theme-location* "The maid rubbed polish onto the table" or *location-theme* "The maid rubbed the table with the polish*"*). Since the sentences have the same order of phrasal constituents (V-NP-PP), the observed priming was probably due to the repetition of thematic roles (targets: *"The man loaded the truck with boxes"* location-theme: *"The man loaded boxes onto the truck"* theme-location).

3.2.2 Information structure

Another level that can play a role in structural priming is information structure. The idea of information structure comes from Prague linguistic circle, specifically Mathesius's topic-focus articulation (*aktuální větné členění*) that was developed in detail

by Jan Firbas (1992) under the name *functional sentence perspective* (FPS). Although different theories use different terminology, the main idea of the group of FPS theories is that old content (topic, theme) and new content (focus, rheme) can be distinguished in a sentence.

The above-mentioned results formulated by Chang and his colleagues (2003) were explained by Bernolet et al. (2009) as a repetition of information structure. They hypothesized that priming is governed by the emphasized binding to thematic roles, with the phrase *"loaded the truck with boxes"* emphasizing *the truck* and "*loaded the boxes onto the truck*" emphasizing *the boxes.* Thus, it is the biding between an emphasized (*theme*) and a thematic role that persist between sentences. In their own experiment, Bernolet et al. (2009) confirmed this idea in cross-linguistic structural priming between Dutch and English. They showed that the Dutch passives, which share a functional assignment but have a different constituent order (PP-initial, PP-medial, and PP-final passives) prime English passive to varying degrees. Dutch PP-medial passives ("*De kerk wordt door de bliksem getroffen"/"The church is by lightning struck"**) prime English passive construction, although they have a different constituent structure, but a common information structure (emphasis on the patient), suggesting that the priming is done by repetition of the information structure. Dutch PP-final passives (*"De kerk wordt getroffen door de bliksem/"The church is struck by lightning")* which share both an information structure and a constituent structure with the English passive, shows a slightly stronger effect than PP-medial passives, probably because priming is present not only at the information structure level but at the syntactic level. Finally, the initial-PP structures *("Door de bliksem wordt de kerk getroffen"/"By lightning is the church struck*"*) elicit fewer English passives than previous Dutch passives, presumably because they emphasize an agent rather than a patient as its English counterpart.

3.3 Conclusion

In conclusion, it can be stated that structure (constituent structure, information structure, thematic role structure) certainly plays a role in priming, but it is still possible that it is only part of the overall effect. Ziegler and his colleagues (2019) questioned the experiment by Bock & Loebell (1990) in which priming between passives (e.g., *The 747 was landing by the airport's control tower*) and intransitive locative sentences (e.g., *The 747 was radioed by the airport's control tower*) was explained on the basis of repeated

phrase structure. Their research has shown that intransitive locatives with other prepositions (e.g., *The 747 has landed near the airport control tower*) do not show a priming effect, leading the authors to conclude that the priming was not due to the repetition of constituent tree structures, but probably due to the adjunct headed by *by* which was repeated between intransitive locatives and passives.

Researchers should be cautious about calling the effect syntactic and about drawing conclusions about the mental representation of syntactic knowledge. As many studies have shown, constituent structure is certainly repeated across sentences, suggesting that priming is in fact syntactic (e.g., Bock 1986; or see a review by Feng et al., 2014); however, the studies cited above suggest that this effect could always be supported by the repetition of another structure level. None of the previous mentioned experiments controlled for all structure levels, and therefore it is possible that the effect was enhanced by a level that was not currently controlled for. Since different structural layers often overlap, it is difficult to determine whether priming is due to the phrase structure or other structural units such as information structure, semantic or thematic roles.

All levels of language exhibit some priming effects (Bernolet et al., 2009; Pickering & Ferreira, 2008; Vernice et al., 2012), so it is useful to design experiments to confirm that the effect is due to abstract syntactic representations and that results are not corrupted by other structural or linguistic repetition. Throughout this work, the more general term structural priming is generally used, and the term syntactic priming is only used when referring to the syntactic part of structural priming.

4. Theories of structural priming

To date, no single definitive theory explains the workings of structural priming, but there are two major theories based on different assumptions. The first is the theory of residual activation and the second is the theory of implicit learning. In addition to these two, alignment theory focuses on the consequences of priming rather than its mechanism. They are introduced in the following section.

4.1 Residual activation theory

The first major account explaining the functioning of structural priming comes from Pickering & Branigan (1998), who explain priming as the residual activation of syntactic representation. In doing so, they draw on Levelt's model of speech production (1993) and Roelofs' explanation of the lemma stratum (1992). In their model, the mental lexicon consists of three levels – conceptual, lemma and word form. At each level there are nodes for individual units that are linked across levels. Word activation spreads from the conceptual layer through the lemma stratum and finally to the word-form stratum, where information about phonological and morphological properties are stored. The lemma stratum holds information about the category of the word, featural information (number, tense, person, etc.), and combinatorial information, that relates to the position a word can occupy in a sentence.

After the formation of the utterance (prime sentence), there is a short-time residual activation of this combinatorial node. The combinatorial node is linked to other verbs that can be used in the same structure, and therefore this structure is more likely to be reused. After the transitive phrase PO is uttered, for example, the used verb activates the PO combinatorial node and the probability of repeated use of the PO phrase increases.

This is consistent with the observation that closed-class words do not affect priming (Bock 1989; Pickering & Branigan 1998). It does not matter whether the prime sentence contains the preposition *for* or *to* (e.g., *The secretary is baking a cake for her boss. / The girl is handing a paintbrush to the man*), both will prime sentences that use the preposition *for* to the same extent, because both are activated by the same PO combinatorial node. Also, because there is a summation of residual activation, the

activation of the same lemma (in this case, verb repetition) along with the combinatorial node will lead to a larger priming effect, thus explaining *lexical boost* (Pickering & Branigan, 1998; Huang et al., 2023).

This model is also consistent with the observation that a single exposure to a prime is sufficient to elicit a priming effect. Melinger & Dobel (2005) demonstrated this effect when they presented participants with isolated verbs in German (Experiment 1) or in Dutch (Experiment 2). These ditransitive verbs are naturally restricted to producing either PO or DO construction. When participants had to describe a transitive scene after the presentation of the isolated verb, a priming effect occurred for the structure for which the isolated verb was restricted. Residual activation theory may explain this by the fact that after the verb was read, the combinational node for the construction was activated in the lemma stratum.

The fact that residual activation is usually considered a transient effect, but structural priming has been found even in situations with 10 intervening filler sentences is an often-cited shortcoming of this account (Bock & Griffin, 2000). Another catch is the cumulative effect of priming. Structural priming has repeatedly been shown to be cumulative over time, with a greater priming effect found in the later parts of the experiment (Hartsuiker & Westenberg, 2000; Kaschak et al., 2006); this cannot be explained by residual activation theory, but by a second prominent approach, implicit learning theory.

4.2 Implicit learning theory

Implicit learning theory argues that priming is caused by long-lasting implicit learning (e.g., Bock & Griffin, 2000; Chang et al., 2000, 2006). Implicit learning is generally understood as the automatic adaptation of a cognitive processing system as a function of experience (Ferreira & Bock, 2006). It can explain priming in a way where "*processing a prime causes adjustments in the connection weights that map between meaning elements and syntactic structure, resulting in a tendency to map the same message elements to the same syntactic configurations*" (Branigan, 2007). The production system learns abstract syntactic relations and then is tuned to reuse them in subsequent language processing, either in comprehension or production. This syntactic knowledge is unconscious, and learning is therefore implicit.

One piece of evidence supporting this mechanism is the *inverse-preference* effect. Poorly known knowledge is generally subject to greater learning as opposed to already well-known knowledge (Ferreira & Bock, 2006). This appears to be true for priming as well, with experiments showing that syntactic structures that are less preferred or have been presented to a lesser extent also exhibit greater priming (Kaschak et al., 2006; Segaert et al., 2011; Branigan & Messenger, 2016). Cumulative priming, meaning that structures are more frequently produced (Hartsuiker & Westenberg, 2000) or better comprehend (Tooley & Traxler, 2018) as the experiment continues is further evidence in favor of an implicit learning effect.

However, there is still debate as to whether this is explicit or implicit learning, and it is possible that it is both. An explicit learning mechanism could store syntactic information as other facts in long-term memory. As can be seen in the example of explicit episodic memory, explicit learning may exhibit the same properties as implicit learning. It can also be that long-lived and less usual memories are easier to remember, which may explain the *inverse-preference effect* (Ferreira & Bock, 2006). Implicit learning takes place without awareness that something is being learned and is usually unaffected in amnesic patients; in contrast, with explicit learning, the person is aware that learning has occurred (Eysenck & Keane, 2005). The occurrence of structural priming in patients with anterograde amnesia is indicative of implicit learning. And the same level of priming was found in amnesic patients as in healthy controls (Ferreira et al., 2005, cited in Ferreira & Bock, 2006).

The fact that conscious concentration on syntactic structures reinforces priming (Bock et al., 1992) argues for explicit learning, which would not be the case for implicit learning. However, Bock and her colleagues did not find this result (1992, in Ferreira and Bock, 2006). They tested the hypothesis that remembered sentences should show a larger priming effect when the mechanism is based on explicit learning. The participants were asked to complete a multiple-choice recognition test regarding the sentences they remembered after the experiment; however, the remembered sentences did not cause greater priming, which does not support an explicit learning mechanism. The study conducted by Heyselaar and her colleagues (2017) on patients with Korsakoff syndrome is further evidence in favor of an implicit learning mechanism in priming. These patients have impaired declarative memory, yet they showed priming tendencies.

However, even the implicit learning model cannot fully explain the mechanism of structural priming. One major shortcoming is that this theory cannot explain how exposure to a single word can induce structural priming, because it views priming as a mapping from message components to syntactic components (Melinger & Dobel, 2005).

4.3 Dual mechanism model

A single mechanism explaining all aspects of priming is still not described. Given that it is possible to observe both long-living and short-living effects of structural priming, it is possible that more cognitive elements are responsible for priming (for the discussion see Branigan, 2007; Ferreira & Bock, 2006). Residual activation for the cognitive representation of abstract structures will be short-lived and therefore not sufficient to explain the effect of abstract priming, which can survive across many interfering sentences. On the other hand, short-lived lexical priming does not exhibit properties of implicit learning because the weighting between the representation of a specific verb and structure in which it occurs will change over longer period of time. A *dual mechanism* model can be obtained by merging the two abovementioned models – residual activation theory and implicit learning theory.

This model was confirmed in a study by Hartsuiker and his colleagues (2008) in both written and spoken paradigms in which short-lived lexical priming effect was observed, but the structural priming was long-lived. Results along the same lines were then obtained by Branigan and McLean (2016) for adults, but also for three- and four-year-old children. Experimental results supporting this theory were also reported in an eye-tracking comprehension study by Tooley and Traxler (2018). Participants in their experiment read complicated reduced-relative sentences (RR) in five sessions, where the verb was always repeated between the prime and target sentences. They found a reduction in fixation times for target sentences within a session, but not across sessions, suggesting a short-lived lexical effect. They also observed a decrease in fixation times in critical regions across sessions, indicating much longer-lasting structural priming. Together, these three studies argue for the dual mechanism model with short-lived lexical priming and a long-lived structural priming effect.

4.4 Interactive alignment theory

Another approach that can shed light on the functioning of priming is alignment theory. The *interactive alignment account* was developed by Pickering and Garrod (2004) and does no primarily attempt to explain the mechanism of priming, but the everyday processing of language in general. However, in doing so, it can tell a great deal about the workings of structural priming. The authors proposed an account in which speech between interlocutors is aligned at many levels, among others at the lexical and syntactic levels (Menenti et al., 2012). The processes involved in speech aligning are mostly automatic and implicit, and this linguistic "common ground" facilitates production and understanding between interlocutors.

Pickering and Garrod (2004) focused on the fact that most studies of language processing are conducted in monologues, but everyday speech is usually carried out in dialogues. Also, many priming studies are conducted in non-social settings that do not reflect the usual state of communication that predominantly takes place in society, with only a minimal amount of speech manifesting as intrapersonal conversation. Interlocutors tend to adapt their speech acts, which leads to a reduction in communicative misunderstandings and facilitates comprehension and speech production, as shown by studies prior to priming (Weiner & Labov, 1983). As noted above, most priming studies are not conducted in dialogues; picture descriptions or sentence completion paradigms are often used, but a strong priming effect was also found in these self-priming studies. The question is whether the function of priming really is the alignment of interlocutors, as predicted by interactive alignment theory, and thus whether it will be greater in a dialogue setting.

In their experiments, Branigan and her colleagues (2000) used a dialogue game in which two speakers described pictures with transitive actions to each other. One speaker was the participant, but the other, a confidant of the researcher, primed the participant with his descriptions of the pictures. A priming effect was found in the dialogue, which provided evidence of a shared syntactic representation between comprehension and speech production, as well as evidence of interlocutor coordination. The study does not explicitly mention communicant alignment because it was done before the theory was formulated, but it speaks for the syntactic alignment in dialogue.

The authors followed this up with a second study (Branigan et al., 2007) in which they sought to discern whether the role of the participant in the communication can

influence the strength of the priming effect. In communication, not only the speaker and the addressee are present, but often an indirect listener. The expectation of alignment theory is that there will be greater syntactic repetition between the speaker and the direct addressee than the indirect addressee. The design in their three experiments was similar to the aforementioned experiment in which people described pictures to each other. The participant and confidant of the experimenter either described the pictures to each other or to a third person. Although there was a structural priming effect for the indirect listener of the description, this effect was larger for the direct addressee of the utterance. This implies that structural priming affects not only the direct interlocutors but also the indirect listener, but on the other hand, this effect is modified by the conversational role. The alignment account was later confirmed by Schoot and her colleagues (2019), who compared priming in isolation with priming in an interlocutor condition, where the later produced a stronger effect.

It appears that alignment is not simply an automatic priming effect but is modified by social and communication factors (Ostrand and Chodroff, 2021). It is apparent that there cannot be an equal sign between priming and alignment. Priming probably influences alignment as a bottom-up process, whereas social and communicative factors influence alignment from the other side as a top-down factors and thus may also modify the strength of the priming effect in communication.

Lastly, it is important to note that alignment theory and implicit learning theory are not in opposition; implicit learning theory explains the mechanisms of the functioning of the effect, and alignment theory focuses on the consequences or function of priming, but both can explain priming as a strengthening of the representation between the semantic and syntactic levels as a function of usage (Ferreira & Bock, 2006).

5. Is there a morphological effect in priming?

Many studies have shown that structural priming requires only a shared abstract structure without the need to share prosodic, semantic or lexical similarities between the target and prime sentences, but it is now known that other linguistic levels also influence the priming effect. One of the challenges of current research on structural priming is to distinguish the different causes of syntactic repetition. Recent discoveries lead to the conclusion that other linguistic entities play an important role in the occurrence of structural priming. For example, Ziegler and his colleagues (2019) have challenged the research of Bock and Loebell (1990), which provided strong evidence for abstract-based structural priming. Their replication suggests that a purely abstract-shared structure does not provide a sufficient explanation for structural priming (at least in the case of passive structures), and that other influences such as the effects of animacy, information structure, event structure, prosody, and shared phonology or morphology should also be considered.

Even if the repetition of abstract syntax were sufficient for priming to occur, it is already known that many of the above factors have an impact on the function of structural priming (expressed in detail in Chapter 3). Of all the possible factors, only two works have addressed the morphology factor, and they have produced conflicting results (Santesteban et al., 2015; Chung & Lee, 2017).

The idea that morphology should affect priming is similar to that of lexical boost. Although priming occurs without the repetition of semantically or lexically related words, the repetition of open class words can enhance priming (Scheepers et al., 2017). Similar effects have been observed for homophones (homophone boost) (Santesteban et al., 2010) and phonemes (Bock, 1987; Lee & Gibbons, 2007). Although not all experiments have reached the same findings (Cleland & Pickering, 2003), it is safe to say that there is a fairly strong interactivity between the different linguistic levels, and a similar effect could be observed for morpheme repetition (*morphological boost*).

Santesteban and his colleagues (2015) were the first to address this issue. They investigated priming in Basque, which is an ergative, head final OV language with morphologically case-marked nominal phrases. The authors conducted a series of experiments in which they observed the structural priming effect in Basque and then focused on the morphological effects of priming. First, they studied whether the

repetition of case-marking endings can produce a priming effect without a complete structural overlap between prime and target. If the repetition of case-marking morphemes can trigger priming without repeating the constituent structure, then the target sentence *Pirate-the*-ABS *depart is* (*The pirate departs;* absolutive NP - V) should more strongly prime the sentence *Doctor-the*-ABS *pirate-the-with bore is* (*The doctor is bored by the pirate;* absolutive NP – PP – V) than the sentence *Pirate-the*-ERG *swim do has* (*The pirate swims*; ergative NP - V), because they share the case marking for the absolutive case. However, this was not found, leading the authors to conclude that repetition of the constituent structure is necessary for structural priming. In a subsequent experiment, they investigated whether repetition of morphology can enhance priming when the structure between prime and target is identical. This was not confirmed either, and the authors concluded that morphology cannot affect structural priming and is therefore processed only after constituent structure selection.

This result is inconsistent with later findings made by Chung and Lee (2017) who found a significant effect of case marking endings on structural priming in Korean. However, their conditions were different, as in Korean, it is possible to omit the inflectional ending for the accusative case. In their experiment, they focused on modulating the presence or absence of the case marking ending. They found that people tended to use the case endings when they were also in the prime sentence and to omit them when they were omitted in the prime sentence, but this was significant only in the condition where the direct object was inanimate. This is in line with previous observations that the accusative case morpheme ending is dominantly omitted for inanimate objects (Aissen, 2003; Lee, 2006). These results suggest that morphology may influence structural priming.

These studies by Santesteban et al. (2015) and Chung and Lee (2017) have produced inconsistent results, which is one reason why it would be beneficial to expand this field. Furthermore, since both studies focused on languages that function differently than Czech, a study in Czech may yield new insight into the interplay between morphology and syntax. A discussion of the differences between the above experiments conducted and the Czech experiment will be preceded by an explanation of how Czech works.

5.1 Czech language and its morphology

Czech is a Slavic fusional language with rich inflectional morphology. As a result, it has a relatively flexible word order. Grammatical roles are not expressed through the position in the structure and prepositional phrases, as in English, but through case ending morphemes, and thus constituents do not have to be in the same linear order. For example, Czech can produce both SVO and OVS ditransitive structures, where the order of recipient and theme are interchangeable (as seen in Sentences 1 to 6).

1. Pán dává kočce jídlo. (ENG.: Man-NOM gives cat-DAT food-ACC. / The man gives the cat food.)
2. Pán dává jídlo kočce. (ENG.: Man-NOM gives food-ACC cat-DAT. / The man gives food to the cat.)
3. Kočce dává pán jídlo. (ENG.: Cat-DAT gives man-NOM food-ACC. / The man gives the cat food.)
4. Kočce dává jídlo pán. (ENG.: Cat-DAT gives food-ACC man-NOM. / The cat is given food by the man.)
5. Jídlo dává kočce pán. (ENG.: Food-ACC gives cat-DAT man-NOM. / The food is given to the cat by the man.)
6. Jídlo dává pán kočce. (ENG.: Food-ACC gives man-NOM cat-DAT. / The man gives food to the cat.)

As can be seen, the subject, direct and indirect object can take almost any position in a ditransitive sentence. Whether a noun is an object or a subject is expressed by the case marking morphemes (Pán–0, nominative; Jídlo-0, accusative; Kočc-e, dative). The above examples do not include all of the possibilities that can be created in Czech. For example, the verb does not have to take the second position and a sentence like Kočce pán dává jídlo (Cat-DAT man-NOM gives food-ACC. / The man gives food to the cat) can be created. All of these structures are possible and understandable, but they express different information structures and are therefore not completely interchangeable.

It is also important to note two things. First, there are approximately 14 declination classes that determine a noun's case marking ending, and in some classes the endings are same for the nominative and accusative (or in other cases depending on the declination class). This can sometimes result in ambiguity. In these cases, the semantic

property of the noun and its animacy are important for the analysis. Secondly, the information structure also plays an important role. Not all of the above-mentioned structures occur with the same frequency. SVO sentences 1 and 2 are dominant (and 1 more than 2), and sentences 3 to 6 are less frequent. Structures 3 to 6 emphasize object and are marked for a specific information structure; although they are grammatical, they are not used as frequently.

However, it is not crucial for processing that these structures are less frequent; a speaker of Czech can understand their meaning on the first reading/hearing (when there is no accidental ambiguity). This means that the listener is not guided (at least in the less frequent structures) by the order of the constituents, but by the case endings of the nouns. This could put the processing of the word morphology on the same level as the processing of structure. This may mean that structural processing may be influenced by the case-marking morphology.

The study by Santesteban and his colleagues (2015) did not support the morphological boost hypothesis. However, it was conducted on the ergative Basque language, which is one of the few representatives of ergative languages in the Indo-European family. This makes Basque quite specific in terms of how it operates with the subject and object of transitive verbs. Basque is also a verb final language (OV). These differences in syntactic structure could lead to a different treatment of syntactic structure compared to non-ergative languages. As a result, this observation may only hold for ergative languages and does not represent conclusive evidence that suffix morphology does not affect structural priming.

The study by Chung and Lee (2017) in Korean also has its own specifics. The authors found an effect of morphology on structural priming, but it was not enhanced by the reuse of the same suffix, but by the omission or appearance of the suffix. Since the omission of the accusative case ending is more likely in informal speech and with the inanimate subject (Chung and Lee, 2017), these are effects that may also play a role in the strategy to omit a suffix, but in Czech these effects should not play a role. In Czech, speakers do not have a choice of whether to use the suffix or not; they have to choose the correct grammatical form. The form can be null-marked and be a bare morpheme, but it is not a choice between using or not using the suffix, as it was in the Korean experiment.

It is also notable that research shows that verb inflection in English ditransitive sentences did not increase the priming effect (e.g., *shows/showed*; Bock, 1989; Pickering and Branigan, 1998). However, the situation in English is also different than in Czech. In verbs, inflectional morphemes have a different function; they do not express cases, as they do in nouns. Verbs also have a relatively stable position in the sentence, and it seems that sentence formation in English is verb-centered (Santesteban et al., 2015), and so verb inflectional morphology may not be as prominent as inflectional morphology in Czech nouns and plays a different role. Czech nouns may occupy different positions in the sentence depending on their thematic role or information structure, and since the case ending is important for identifying this role, it may play a more important role and be more strongly associated with a particular structural position in Czech speakers. This association between morphology and a certain constituent could possibly be primed and enhance structural priming.

6. Goals and research questions

The main aim of this thesis is to investigate the functioning of structural priming in Czech production. Since structural priming has not yet been confirmed in Czech, the first step is to find out whether structural priming occurs in Czech, and then to look at other effects that accompany it.

A replication of Bock's (1986) study will be carried out to investigate the effects of priming. The structural differences between English and Slavic languages do not allow Bock's study to be replicated with stimuli with the same syntactic structures. On the other hand, this is a good opportunity to investigate the functioning of structural priming in conditions where word order may alternate, which is one of the basic characteristics of structural priming.

Bock used alternation of voice, and alternation of ditransitive dative structures. The passive voice is not used as often in Czech as it in English, so sentences in which the passive voice appeared in Bock's experiment were transformed into nominative/accusative (NOM/ACC) transitive constructions. Due to the free word order, nouns can change their position in Czech sentences, which can serve as an alternative to active/passive sentences (e.g. *Medvěd žere rybu/Rybu žere medvěd*; *Bear*-NOM *eats fish*-ACC/ *Fish*-ACC *eats bear*-NOM. These sentences resemble passives because they emphasize the object (OVS) or actives because they emphasize the subject (SVO). Similarly, prepositional and double-object dative constructions were changed to constructions with an alternation of word order. This was possible because Czech does not use prepositional phrases to express the recipient role, but uses a case-marking morphology (*Pošťačka dává babičce dopis/Pošťačka dává dopis babičce; Postwoman is giving the grandmother*-DAT *a letter*-ACC/*The postwoman is giving a letter*-ACC *to the grandmother*-DAT.

The other goals focus on other aspects that may affect priming. The first phenomenon investigated is the well-described *lexical boost* (Scheepers et al., 2017; Traxler et al., 2014). Another area of focus is morphology, specifically the boosting effect of case-marking endings on priming. The inconclusive results from previous experiments in Basque and Korean (Santesteban et al., 2015; Chung & Lee, 2017) imply that this area could benefit from research in a new context. It is possible that in Czech, where more emphasis is placed on case morphology than on the constituent order, case marking can enhance structural priming. The third element focused on is working

memory and its connection to priming. Both residual activation theory and implicit learning theory posit that working memory could reinforce structural priming, albeit through slightly different mechanisms. According to implicit learning theory, individuals with higher working memory capacity should exhibit stronger priming effects because they are more proficient at retaining and accessing learned structures. Residual activation theory posits that exposure to a particular sentence structure leaves behind residual activation in working memory, so individuals with higher working memory capacity are better able to sustain and utilize the activated structures.

Based on these goals, the following research question were formulated:

1. Is there an effect of structural priming in Czech language production?
2. Can repetition of a lexical element influence the structural priming effect in Czech (lexical boost effect)?
3. Can repetition of a morphological element influence the structural priming effect in Czech (morphological boost effect)?
4. Can working memory influence the structural priming effect?

7. Experiment 1

The aim of the first experiment was to replicate the existence of a structural priming effect in the production of Czech sentences. The experiment is based on a classic study conducted by Bock (1986) and uses the same picture description task. In this task, the participant reads the presented sentence and then describes the displayed picture. The use of the same syntax during the picture description indicates the occurrence of structural priming. Used as primes were two different sentence constructions with interchangeable word order.

The first constructions used were transitive sentences with alternating SVO/OVS word order (Sentences 1 and 2). Neutral non-transitive sentences (Sentence 3) were also used, for comparison with the prime condition.

1. SVO prime: Koza žrala trávu na louce. (ENG: *A goat was eating grass in a meadow*.)
2. OVS prime: Trávu žrala koza na louce. (ENG: *The grass was eaten by a goat in a meadow.*)
3. Neutral prime: Orangutan řval moc hlasitě. (ENG: *The orangutan roared very loudly.*)

Ditransitive sentences were the second structure used. They could take the form in which the patient (dative case) precedes the object (accusative case) or vice versa (sentences 4 and 5). Neutral structures (sentence 6) were also included for comparison purposes (sentence 6).

4. DAT/ACC prime: Veterinářka stříhá psovi drápy. (ENG: *A vet is clipping the dog's claws.*)
5. ACC/DAT prime: Veterinářka stříhá drápy psovi. (ENG: *The vet is clipping claws of the dog.*)
6. Neutral prime: Zajíc běží do lesa. (ENG: *The rabbit is running into the forest.*)

In addition, the first experiment attempted to replicate the lexical boost effect, which is well established in English. Therefore, in half of the sentences, the verb could be

repeated between the prime sentences and the target pictures, and in the other half, it is difficult to reuse the same verb.

Based on these goals, the following research questions were formulated:

1. Is there a structural priming effect in the production of Czech sentences?
2. Is structural priming in Czech enhanced by verb repetition (lexical boost effect)?

7.1 Method

7.1.1 Participants

The experiment involved 62 students (53 women) from the LABELS pool (Laboratory of Behavioral and Linguistic Studies), a joint laboratory of Charles University's Faculty of Arts and the Institute of Psychology of the Academy of Sciences. This pool includes mainly students who receive credit for their participation, and a few volunteers. The average age of the participants was 20 years (range 17-35 years).

7.1.2 Materials

Each trial consisted of a prime sentence and a target picture that had to be described. Half of the prime sentences were transitive SVO or OVS sentences (sentences 1 and 2) and the other half were ditransitive sentences with ACC/DAT or DAT/ACC syntax (sentences 5 and 6). The place adjunct was added to the end of these SVO/OVS sentences to make them similar in length to the filler sentences and to make them sound more natural. The adjunct should have no effect on priming. In addition to these priming sentences, a neutral condition was also included (sentence 3 and 6). The neutral condition had a different syntax than the priming sentences and was added to measure the syntax primarily used to describe the image in the non-priming condition. A list of the experimental stimuli can be found in Appendix A.

Transitive SVO/OVS or ditransitive primes were followed by a different set of pictures. Target pictures after transitive SVO/OVS sentences were drawn so that the same structures could be used to describe them (e.g., The bear eats the fish); similarly, pictures after ditransitive sentences depicted ditransitive events (e.g., The postwoman gives a letter to the grandmother). It was up to the participants to decide which of the two alternatives to use to describe the picture (e.g. OVS or SVO). As language is highly

creative, it is of course possible that in some cases participants will use different syntax than anticipated.

Half of the target pictures were drawn in such a way that the same prime verb could be repeated when describing this picture. This manipulation allowed the effect of lexical boost to be tested. When the target sentences with repeated verbs have more syntax repetition, this would indicate a lexical boost effect.

Sentences with intransitive structures, and images that were difficult to describe in a transitive way (depicting intransitive events), served as filler pairs (e.g., "The alarm clock is ringing on the table"). One version contained 36 sentence-picture filler pairs. Two filler pairs were always inserted between the prime-target pairs. The type of the prime-target pair (transitive SVO/OVS or ditransitive) was alternated. That is, before describing the target picture with the same structure again (e.g., ditransitive), the participant described 5 pictures and read 5 sentences with different syntactical structures.

In total, the experiment contained 18 different prime sentences for SVO structures and 18 of their OVS alternations, as well as 18 ditransitive ACC/DAT sentences and an equal number of their alternations (DAT/ACC). Three different versions of the experiment were used to balance the conditions. That is, one target picture was preceded in one version by one possible syntax (e.g. SVO), in the second version by its alternation (e.g. OVS), and in the third version by a “neutral” syntax. Thus, one participant saw 6 SVO sentences, 6 OVS sentences, as well as 6 ditransitive ACC/DAT sentences, 6 ditransitive DAT/ACC sentences, and also 12 “neutral” sentences. The verb repetition condition was nested within the items. In all versions, the same target pictures could be described in the lexical boost condition, but in each version, they were preceded by a different sentence structure (e.g., SVO, OVS, or neutral). Table 1 shows the design and number of structures seen by each participant in each version.

Table 1

Design of Experiment 1

Target picture	Prime structure	Verb repetition	Number of sentences
SVO/OVS	SVO	Yes	3
SVO/OVS	SVO	No	3
SVO/OVS	OVS	Yes	3
SVO/OVS	OVS	No	3
SVO/OVS	Neutral	-	6
Ditransitive	Ditransitive ACC/DAT	Yes	3
Ditransitive	Ditransitive ACC/DAT	No	3
Ditransitive	Ditransitive DAT/ACC	Yes	3
Ditransitive	Ditransitive DAT/ACC	No	3
Ditransitive	Neutral	-	6

7.1.3 Procedure

The task was disguised as a memory experiment. The aim was to avoid revealing the true purpose of the experiment, which might affect the participants' language production. In the first part, which served as a masking task, participants were shown stimuli in the form of sentences and pictures. The task was to memorize the stimuli and then recognize them in the second part. The stimuli were presented one after the other in alternating order, with the picture always following the sentence. The participants' task was to read the sentence aloud or, when shown the picture, to describe it in one sentence and to remember these sentences and pictures in order to recognize them later. The experiment was self-paced, but participants were instructed to proceed as quickly as possible. The stimuli from the learning phase served as fillers in the second experiment phase and had a different syntactic structure than the priming sentences.

The second part of the experiment, involving recognition, actually measured structural priming. The task looked similar to the first phase. Participants saw the stimuli in alternating order and had to read sentences aloud or describe pictures. However, they then had to decide whether the stimulus was new or repeated from the previous section by simply stating “yes” or “no”. Note that this means that the sentences did not follow directly after each other, but were punctuated by these short one-word

statements. All prime-target pairs were novel to the participants. The session was recorded on a voice recorder and later transcribed.

7.1.4 Scoring

As OVS sentences, the structures with simple OVS order were evaluated (Vojáka bodla vosa; *The soldier was stung by a wasp*), and as SVO sentences, the structures with SVO word order were evaluated (Princezna hladí králika, *The princess pets the rabbit*). However, sentences containing adjuncts, usually expressing direction, place or manner, were also accepted. They could be expressed as a prepositional phrase (*Bača nese ovci* na zádech*, A shepherd carries a sheep* on his back) or as a single word (*Ovčák nese jehně* domů*, A shepherd carries a lamb* home). Sentences in which the adjunct was expressed at the end of the structure, the same as in the initial sentences, as well as sentences in which it was expressed in a different position (*Pastevec nese* na ramenou *ovci*, *A shepherd carries* on his shoulders *a sheep*) were marked as correct structures.

Similar rules were applied to ditransitive structures, where simple repetition of the transitive syntax was accepted (Karkulka drhne vlkovi zuby, *Little Red Riding Hood is scrubbing the wolf's teeth*), as well as sentences with an adjunct (*Jeníček krade perník ježibabe* z chaloupky*, Hansel steals gingerbread from the witch's* cottage), or sentences in which the adjective or pronoun expanded the noun in the same case (*Maminka myje hlavu* své *dceři*, *Mom is washing* her *daughter's head*).

7.1.5 Analysis

A generalized linear mixed-effects model (GLMM) was used for statistical analysis using R (R Core Team, 2021) and the packages lme4 (Bates et al., 2015) and car (Fox & Weisberg, 2019).

The analysis was conducted using two models. The first model tested whether there was an overall priming effect in Czech language production, and included Prime type (neutral/DA/AD) as a fixed effect. The second model focused on the lexical boost effect and included prime type (AD/DA), verb repetition (same/different) and their interaction as a fixed factor.

Participants and items were used as random intercepts for both models. The two constructions examined (SVO/OVS and ditransitive structures) were analyzed in

separate analyses. The outcome variable was the type of target construction with two levels that depended on the analysis (SVO/OVS or AD/DA).

7.2 Results and discussion

7.2.1 Overall priming effects

The total sum of the collected target responses was 2 232 sentences (including responses after neutral primes). Of this number, 1 196 sentences were coded as "other" responses. These were responses that provided structures other than those that could be coded as transitive OVS/SVO or ditransitive structures as it was defined in the previous section. In terms of legitimate targets, 595 SVO responses were collected, but only 9 with OVS structure (see Table 2). For ditransitive structures, the number was more balanced, namely 234 for ACC/DAT and 198 for DAT/ACC structures (see Table 3 and Figure 1).

Table 2

Absolute and relative frequency of responses to OVS/SVO target pictures after different prime sentences in Experiment 1

	Absolute		Relative	
	SVO target	OVS target	SVO target	OVS target
SVO prime	200	3	0.33	0.005
OVS prime	200	3	0.33	0.005
Neutral prime	195	3	0.32	0.005
Together	595	9	0.99	0.01

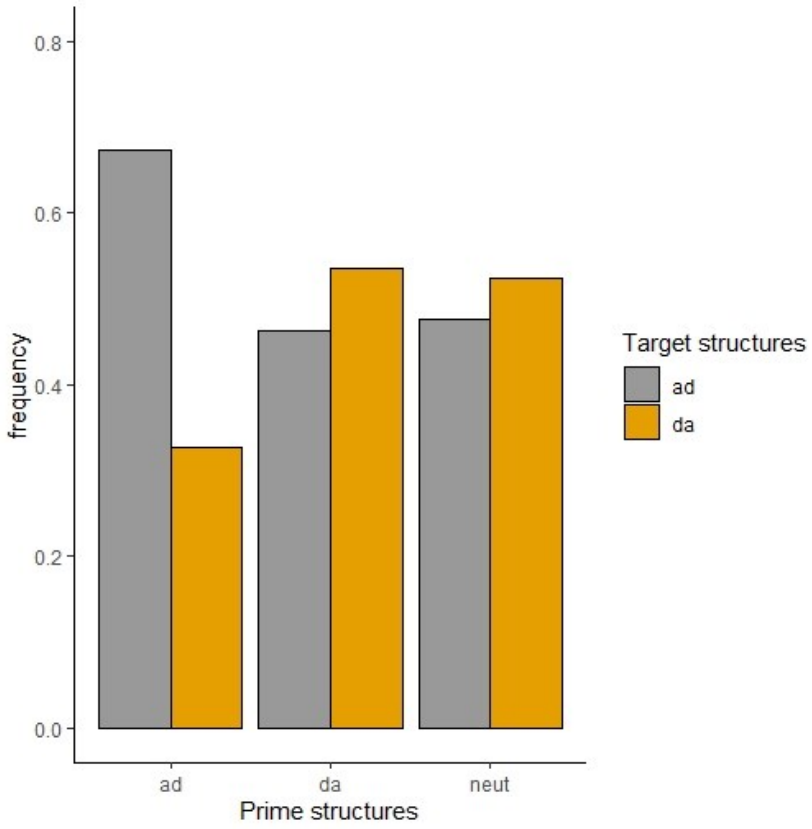
Table 3

Absolute and relative frequency of responses to ditransitive target pictures after different prime sentences in Experiment 1

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	81	70	0.19	0.16
ACC/ DAT prime	50	103	0.12	0.24
Neutral prime	67	61	0.16	0.14
Together	198	234	0.46	0.54

Figure 1

Relative frequencies for ditransitive targets after different primes in Experiment 1



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

The results were calculated separately for SVO/OVS targets and ditransitive targets. There is almost no variability in the SVO/OVS condition (Table 2), so it was not tested for effect in these constructions. Presenting transitive sentences with OVS structures does not increase the production of OVS structures in picture descriptions. Due to their lack of variability, it will not be possible to detect priming tendencies. Since most people (99 %) used SVO syntax, this alternation of simple transitive sentences is not suitable for priming studies. In a subsequent analysis examining the effect of lexical boost, SVO/OVS structures were omitted.

On the other hand, ditransitive primes showed a significant effect on the production of ditransitive sentences. A significant effect was found only for ACC/DAT structures compared to the neutral condition ($p > 0.001$) and not for DAT/ACC structures compared to the neutral condition ($p = 0.513$; Table 4). Given that ACC/DAT syntax is less frequent in Czech, this confirms the inverse preference effect, where less frequent structures elicit a stronger effect (Ferreira & Bock, 2006). An explanatory Anova analysis used on the GLMM evaluated the whole term, which confirmed that prime structure is significant ($p < 0.001$) in predicting the target construction ($\chi^2 = 21.3$, Df = 2). Anova tests the overall effect of each fixed effect, while GLMM focuses on individual fixed effects.

Table 4

Results model for ditransitive sentences in Experiment 1

Parameter	Estimate	SE	P-value
Intercept	0.064	0.318	-
Factor DAT/ACC	0.193	0.295	0.513
Factor ACC/DAT	-1.092	0.303	0.001 ***

Note. The response variable is target structure.

7.2.2 Lexical boost effect

The second model focused on the effect of verb repetition (lexical boost effect) on structural priming. Since the SVO/OVS syntax did not prove suitable for priming studies, the model was applied only to ditransitive structures.

Table 5 shows the absolute frequency and Figure 2 the relative frequency of target responses for the condition where the verb was repeated (same) or not repeated (different) in the prime and target sentences. The data presented in Figure 2 show that in each condition, the syntax of prime is preferred when describing the target picture, except for the DAT/ACC structure where the verb was not repeated across sentences (DIFF). This may mean that structural priming must be reinforced to be detected, either by an inverse preference effect or by lexical repetition of the verb.

In the second model, the neutral level of the prime type factor was omitted because it makes no sense to talk about verb repetition between "neutral" primes and their target sentences. All target sentences would automatically fall into the category *different* (no verb repetition). For this reason, the coding was changed from treatment to sum (prime type: ACC/DAT coded as 1 and DAT/ACC as -1; verb repetition: different verb coded as 1 and same verb as -1). In other words, the analysis focused on the main effect and tested whether levels of one factor had an effect independent of levels of the other factor. There is no difference between the treatment or sum coding when calculating higher-order interactions.

In this model, the effect of priming structure was again observed. However, the effect of verb repetition, either alone or in interaction, was not found. Although the descriptive statistics seem to be consistent with the lexical boost hypothesis, the results are not significant (Table 6). Verb repetition does not enhance the effect of structural priming In Czech language production.

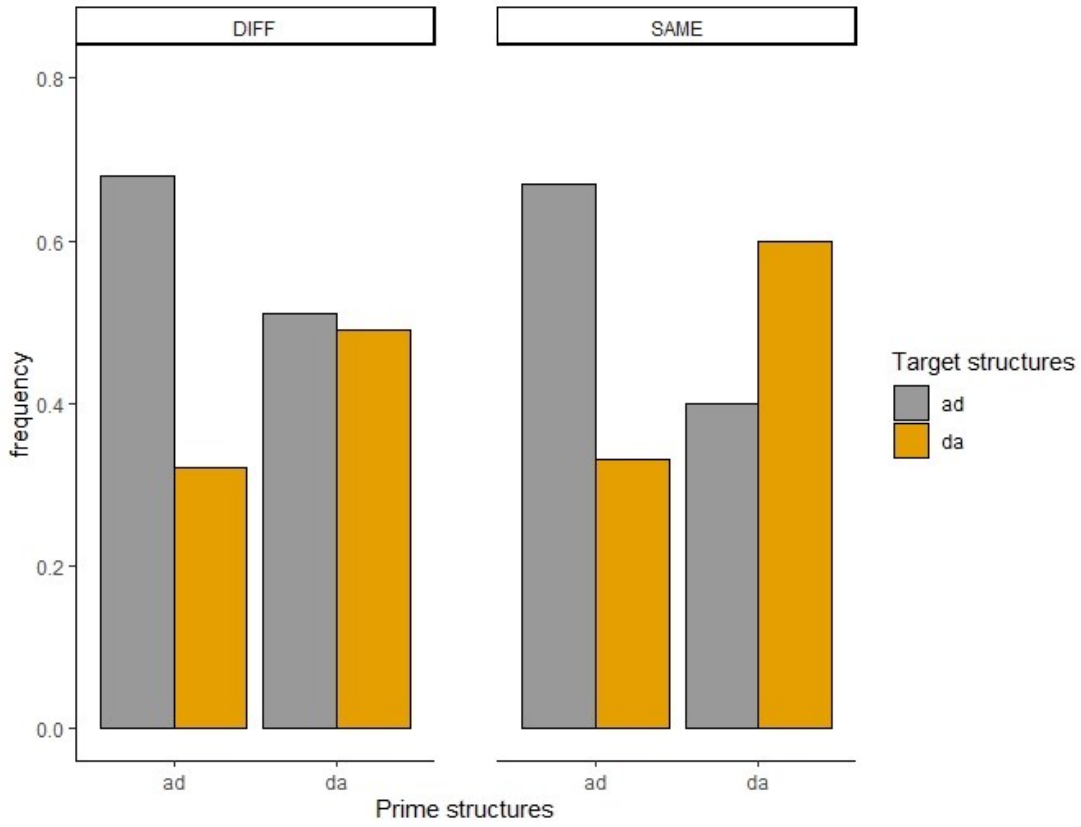
Table 5

Absolute frequencies of responses to ditransitive target pictures after prime sentences in condition with repeated or unrepeated verbs in Experiment 1

	Same verb		Different verb	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	39	27	42	43
ACC/ DAT prime	23	46	27	57
Together	135		169	

Figure 2

Relative frequencies of responses to ditransitive target pictures after prime sentences in condition with repeated or unrepeated verbs in Experiment 1



Note. Frequencies are calculated for each prime condition separately. DIFF represents condition with repeated verbs and SAME represents the condition with unrepeated verbs. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

Table 6

Second results model for ditransitive sentences in Experiment 1

Parameter	Estimate	SE	P-value
Intercept	-0.363	0.285	-
Factor ACC/DAT	-0.664	0.160	3.54e-05 ***
Factor Different	-0.330	0.214	0.123
Interaction Prime type & Verb repetition	0.117	0.156	0.450

Note. The response variable is target structure.

8. Experiment 2

After the first experiment found that structural priming can be investigated in Czech on ditransitive constructions, an attempt was made to investigate its relation to morphology. Lexical boost is well documented in psycholinguistic literature (e.g., Cleland & Pickering, 2003), and the results in Experiment 1 were consistent with previous studies, although the effect was not statistically significant. Nevertheless, it is possible that a similar effect could operate at the morphological level. Czech marks the cases of nouns with different endings based on the grammatical gender and class of the noun. The repetition of a case ending morpheme could strengthen the link between morphemes and syntax, and people might be more likely to use the same syntax for nouns with the same case endings. That means that prime 1 (Sentence 1) should prime target 1 (Sentence 2) more than prime 2 (Sentence 3) should prime target 2 (Sentence 4), because prime 1 and target 1 share the same case-marking morphemes.

1. Same suffix prime: Inženýr posílá šéf *-ovi* obálk *-u.*
   (*The engineer sends an envelope to the boss.*)
2. Same suffix target: Sestřička podává doktor *-ovi* vod *-u.*
   (*A nurse is giving the doctor water*.)
3. Different suffix prime: Pošťák vydává sluh *-ovi* krabic *-i*.
   (*The postman gives the servant the box.*)
4. Different suffix target: Mechanik opravuje žen *-ě* motork *-u.*
   (*A mechanic repairs a motorcycle for a woman*.)

The two main theories of priming, residual activation theory and implicit learning theory, both predict that greater working memory capacity should yield stronger priming effects. Thus, another goal of Experiment 2 was to examine the relationship of priming to working memory. If there was a relationship, people with better working memory might be more affected by priming tendencies than people with poorer working memory. Therefore, the following questions were formulated in Experiment 2:

1: How does the repetition of case ending morphemes (morphological boost effect) between prime and target nouns affect the structural priming effect in Czech language production?

2: Can working memory affect the structural priming effect in Czech language production?

8.1 Method

8.1.1 Participants

Similar to Experiment 1, in Experiment 2 there were 63 individuals (53 females) from the LABELS pool, mostly students, who received credit for their participation. The average age of the group was 21.7 years (range 18-34 years).

8.1.2 Materials

The experiment follows the same procedure as the previous experiment, but a few changes had to be be implemented. Transitive SVO/OVS structures were no longer used because they cannot be primed, and only ditransitive structures were used. The sentences and pictures from Experiment 1 could not simply be reused because it was necessary to control the case endings of the nouns, so a new set of stimuli was created.

Together with the 24 new ditransitive prime sentences, 24 new target images were created. Since in one version the prime sentence was presented in ACC/DAT syntax, in the second version the same sentence was in DAT/ACC syntax, and in the third version it was replaced by a neutral sentence. A total of 72 different sentences were used. In all versions, a particular sentence, its syntactic alternation, or neutral structure was associated with the same target image. Thus, one third fewer images were used, namely only 24.

Half of the sentence-picture pairs were constructed in such a way that it was possible to repeat the case ending morphemes when describing them, and half in such a way that it was difficult or almost impossible to repeat case marking endings.

For the same condition, either feminine nouns were used that end in the morpheme *-e* in the dative case and and were assigned to pictures to pictures in which the recipient is in feminine grammatical gender and could also be expressed with word ending *-e*; or masculine animate nouns were used that adopt the morpheme *-ovi* in the dative and they were assigned to pictures depicting recipients with the same endings.

For the accusative case in the same suffix state, the ending *-u* was always used, an ending for grammatically feminine nouns in one declension class. For a sentence to be recognized as repeated in the same suffix condition, the participant had to repeat both case endings, for dative (corresponding to *-e* or *-ovi*) and accusative (*-u*). For the different condition, the opposite strategy was used, and sentences were matched to pictures that would have nouns with different endings.

Fillers from Experiment 1 were reused, some images that describe SVO sentences that did not show a priming effect in the first experiment were also used as fillers. During presentation, two filler pairs were always inserted between the prime-target pairs, so that people always read or said 4 sentences before reaching the next transitive target pair.

It is possible that people will repeat only syntax and not suffixes between primes and targets in the same suffix condition. This would mean that target descriptions from the same suffix condition that are primed but do not have the same suffixes as primes will fall into the different suffix condition in analysis. This also means that more target description will likely be collected in the different suffix condition than in the same suffix condition, even though they have equal numbers in the design.

Word span tasks and digit span tasks were used to measure working memory. Digit span tasks consisted of forward and backward digit span tasks. The forward test is considered easier and was therefore presented first. The task consisted of a sequence of numbers which participants had to repeat after the experimenter. The set of digits was increased after two correct answers. In the backward span task, the participant is asked to repeat the numbers in reverse order. After two unsuccessful attempts, the task was terminated, otherwise it continued until the number of digits from the list reached the maximum of 9 in the forward span task or 8 in the backward span task.

In the word span task (von der Malsburg, 2015), participants were asked to evaluate the logical correctness of a sentence (e.g., Kdo dostane spoustu informací a zpracovává je, často potřebuje bicykl k jídlu. ENG: *Whoever gets a lot of information and processes it, often needs a bicycle to eat* – correct answer: improper) and try to remember the words that appeared between the sentences. After a random number of sentences, participants were asked to write the words they remembered, in the same order they appeared. There was a total of 105 words in the task.

8.1.3 Procedure

The priming procedure was the same as in Experiment 1. After the priming task, subjects were presented with the word and digit span tasks, whose order was counterbalanced.

8.1.4 Scoring

Sentences were scored in the same way as ditransitive sentences in Experiment 1 with one exception - deverbative adjectives in place of verbs were also accepted. These also express action but transpose it into a property of the noun, e.g., *Princ* nazouvající *ženě střevíc* (Prince *slipping* a shoe on a woman). In 22 cases (out of a total of 490), ditransitive descriptions with deverbative adjectives instead of verbs occurred.

8.1.5 Analysis

The analysis was same as in Experiment 1, and again two models were used, one for the overall priming effect and one for the boosting effect. The only difference was that the second model focused on the morphological boost effect and not on the lexical boost.

Pearson's correlation coefficient was used to analyze the relationship between priming tendency and working memory, and the different working tasks with each other.

8.2 Results and discussion

8.2.1 Overall priming effects

The total number of 1 512 target sentences were collected, of which 1 022 were coded as “other” constructions and 490 as ditransitive construction. The ratio of DAT/ACC to ACC/DAT was 233:257, almost a 50/50 split, but people preferred to reuse the syntax they had been exposed to in the prime sentences (Table 7, Figure 3). The ratio of structures was equal when describing target after a neutral sentence.

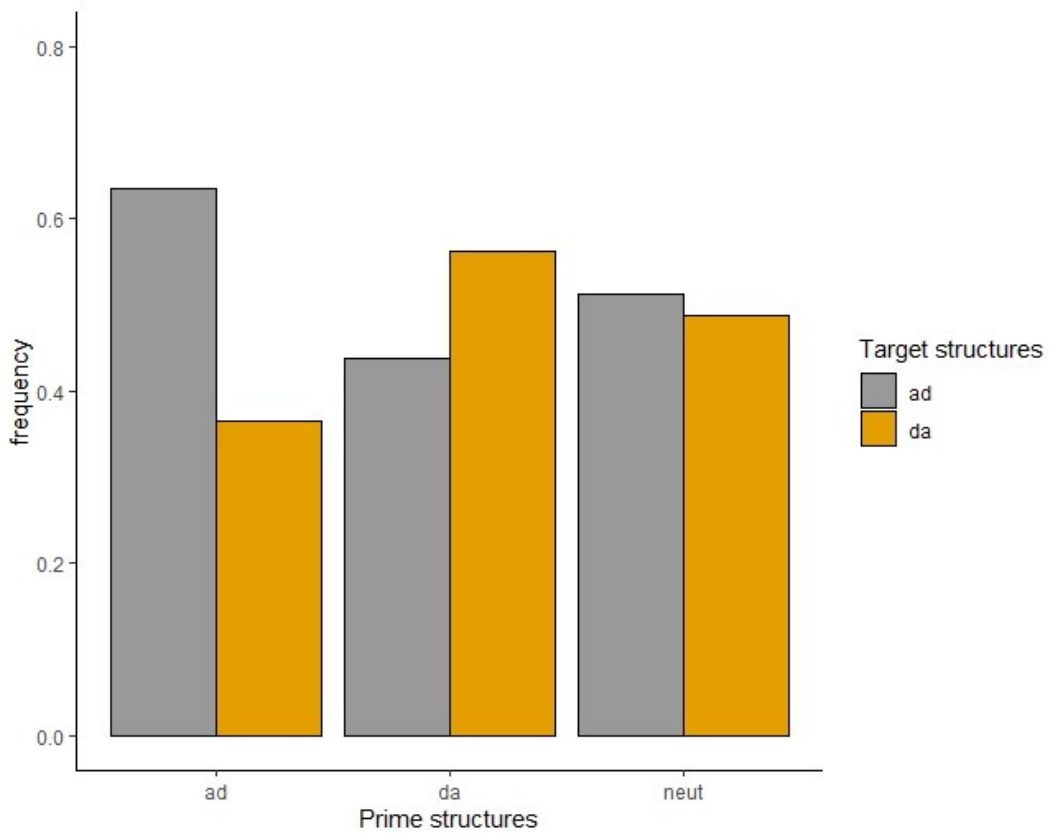
Table 7

Absolute and relative frequency of responses target pictures in Experiment 2

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	100	78	0.20	0.16
ACC/ DAT prime	57	99	0.12	0.20
Neutral prime	76	80	0.16	0.16
Together	233	257	0.48	0.52

Figure 3

Relative frequencies for ditransitive primes after different primes in Experiment 2



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

In the first model, the overall effect of priming was tested. A significant priming effect was found for ACC/DAT structures and a nonsignificant effect for DAT/ACC structures (Table 8), replicating the result from Experiment 1. The explanatory Anova analysis on the GLMM was also significant (p=0.001), confirming the result (χ^2 = 13.88, Df = 2).

Table 8

Results model for ditransitive sentences in Experiment 2

Parameter	Estimate	SE	P-value
Intercept	-0.209	0.276	-
Factor DAT/ACC	0.392	0.246	0.111
Factor ACC/DAT	-0.555	0.259	0.032 *

Note. The response variable is target structure.

8.2.2 Morphological boost effect

Table 9 shows the absolute frequency and Figure 4 the relative frequency of target responses for conditions where case-ending morphemes were repeated in target sentences (*same* condition) or not repeated (*different* condition). All frequencies are in favor of the priming effect.

In the second model, the morphological boost effect was tested. As in Experiment 1, the neutral condition was left out, as there is no possibility of neutral primes in front of the same suffix targets. The fixed effects were sum coded (prime type – ACC/DAT coded as 1 and DAT/ACC as -1; case ending morpheme repetition – different morpheme coded as 1 and same morpheme as -1). An effect of priming was confirmed (p > 0.001), but no effect of suffix repetition (p = 0.533) or its interaction with syntax on priming tendencies (p = 0.773; Table 10) was found.

The smallest difference between the production of DAT/ACC or ACC/DAT targets occurs after DAT/ACC primes in the condition where the suffixes are not repeated (Figure 4). This is the prime sentence that cannot be boosted by the inverse preference effect. The same pattern was observed in the previous experiment, where a lexical boost effect was searched for. This supports the idea that the priming effect must be boosted in order to be strong enough to be detected in the situation that was used. However, it

has not been confirmed that the repetition of case-ending morphemes enhances the structural priming effect in Czech.

Table 9

Absolute frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 2

	Same suffix		Different suffix	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	33	21	67	57
ACC/ DAT prime	17	26	40	73
Together	97		237	

Table 10

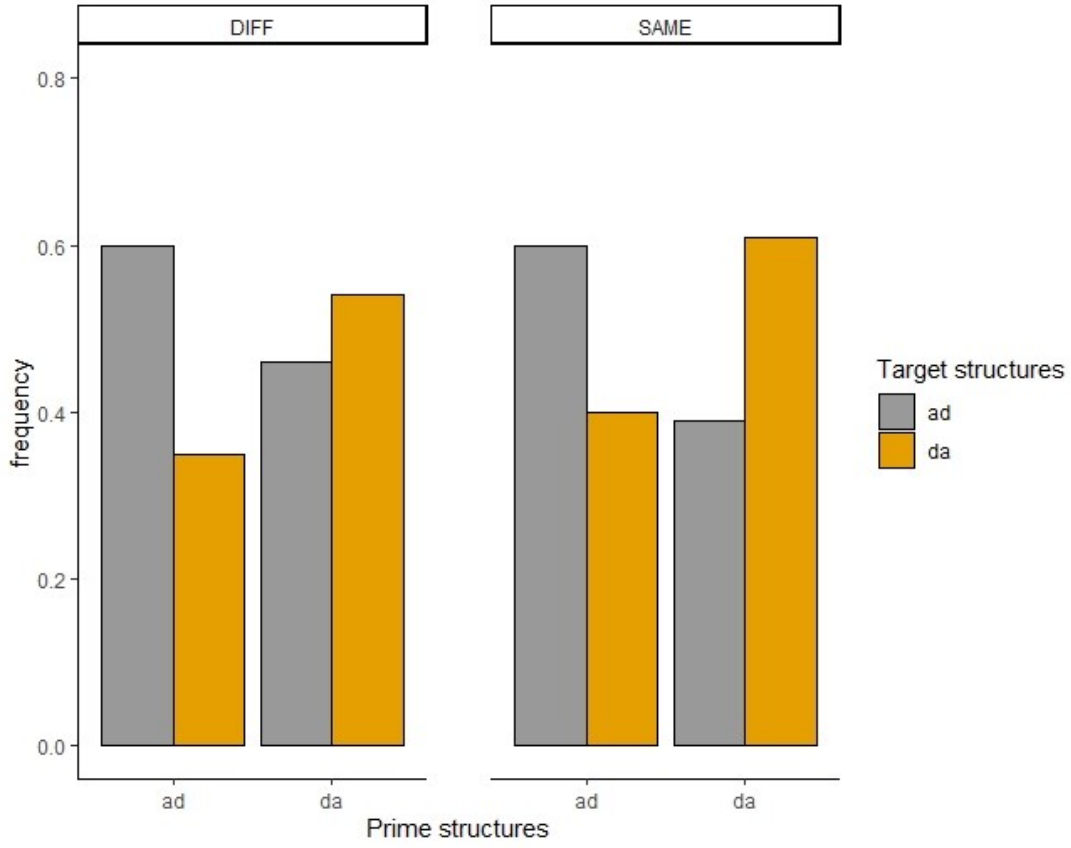
Second results model for ditransitive sentences in Experiment 2

Parameter	Estimate	SE	P-value
Intercept	-0.197	0.219	-
Factor ACC/DAT	-0.466	0.139	0.001 ***
Factor Different	-0.101	0.162	0.533
Interaction Prime type & Suffix repetition	0.040	0.137	0.773

Note. The response variable is target structure.

Figure 4

Relative frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 2



Note. Frequencies are calculated for each prime condition separately. SAME represents condition with repeated morphemes and DIFF represents the condition with unrepeated morphemes. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

8.2.3 Effect of working memory

The second question was if there is a relationship between priming and working memory. Individuals with better working memory might have greater priming tendencies. A weighted score of the number of primed sentences ([number of primed targets*number of all transitive targets]/number of all possible transitive targets) served as a measure describing priming tendencies. The relation was calculated using Pearson's correlation coefficient separately for the word memory task and separately for the number memory task. Due to an error in the word span program, only values for 42 participants in the word span task were collected.

For digit span analysis, a single cumulative score was calculated for both digit span tasks (forward and backward) and correlated with the weighted priming score. No correlation was found (r = -0.050, p = 0.70; Figure 5). The proportion of correctly remembered items was used to analyze the memory span for words, which was correlated with the weighted priming score. Again, no significant relationship was found (r = 0.021, p = 0.89; Figure 6). The answer for the second research question is that people with better working memory are not affected by structural priming to a greater extent than people with worse working memory.

Figure 5

Correlation between weighted priming scores and digit span tasks in Experiment 2

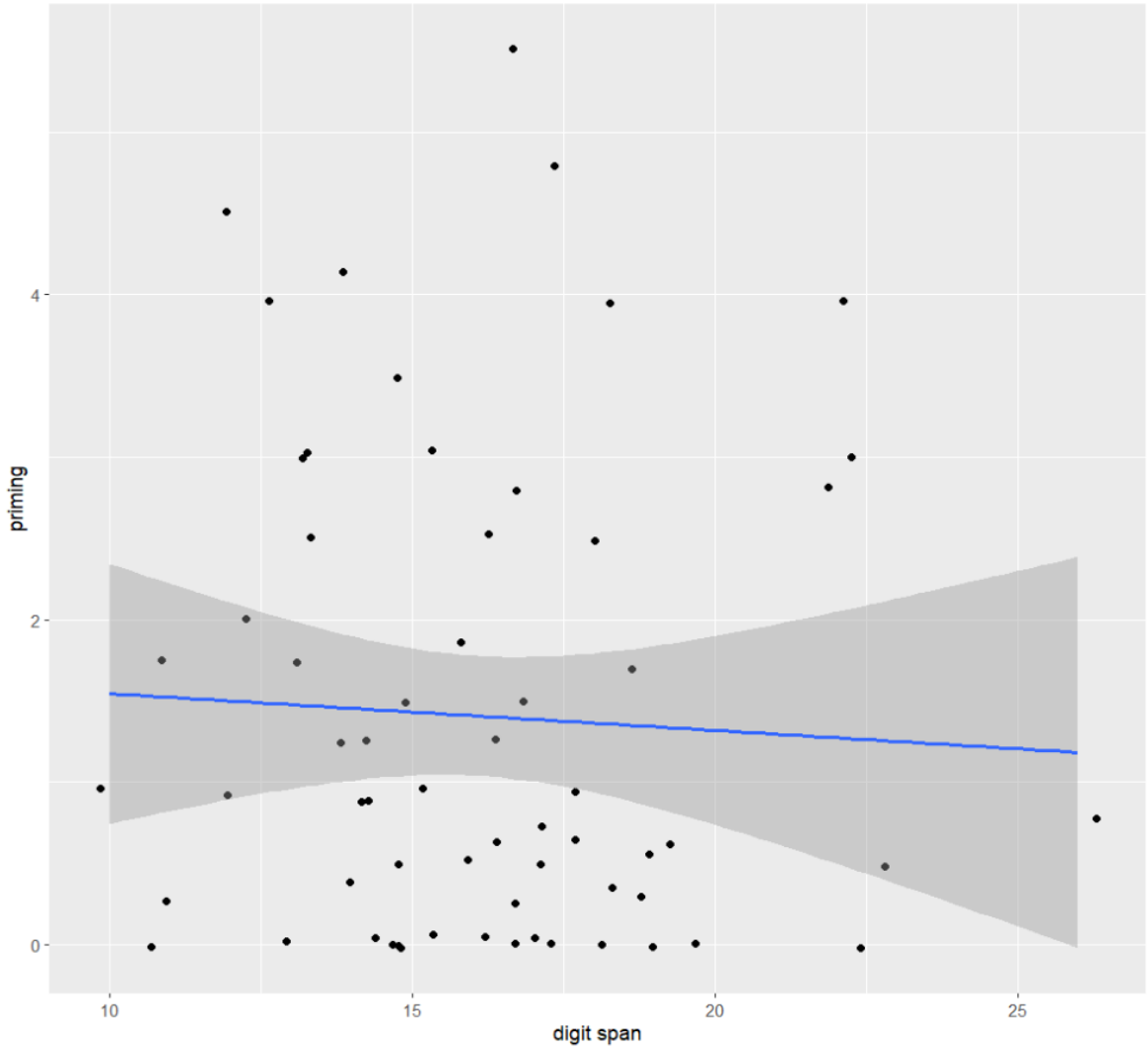
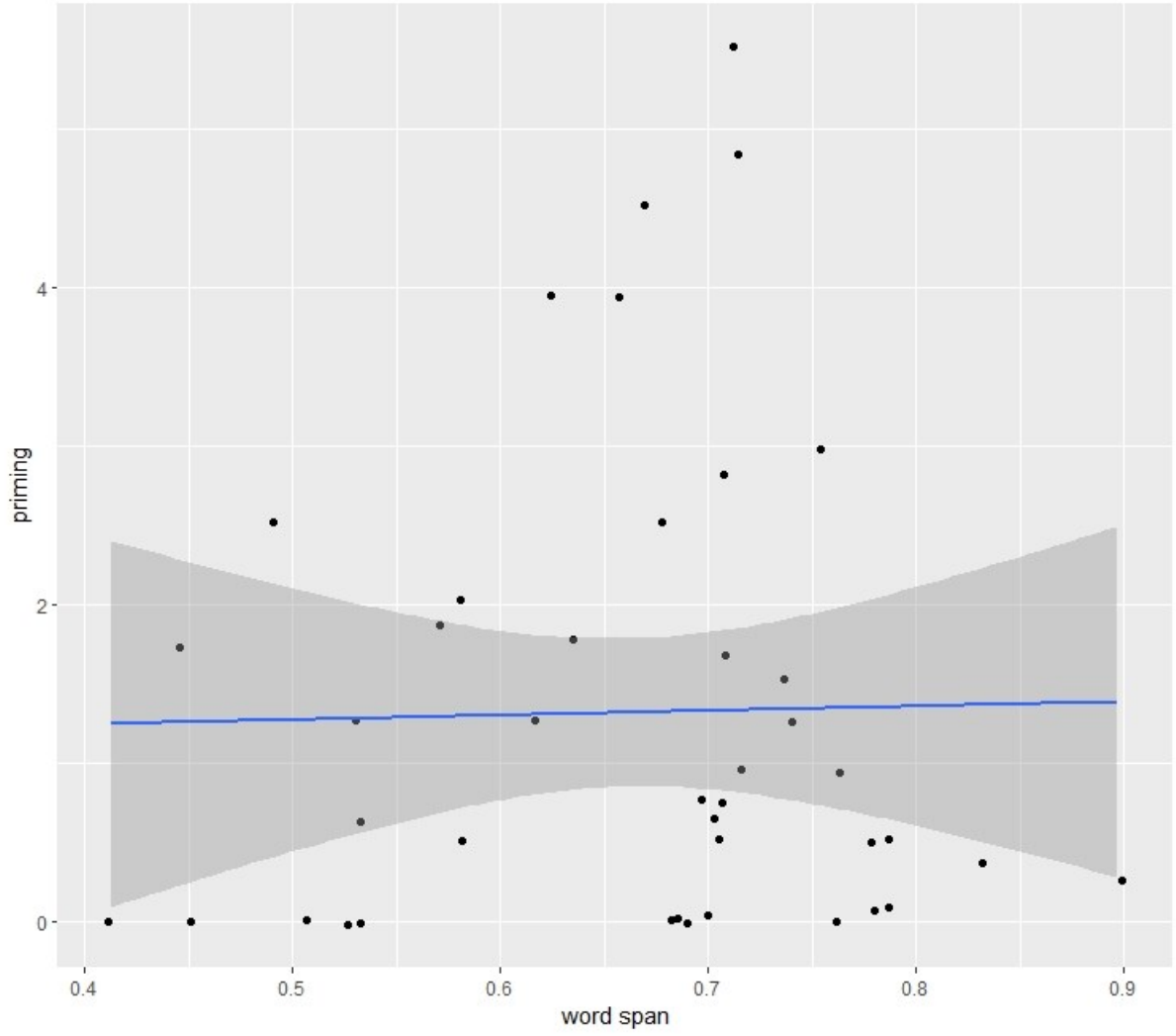


Figure 6

Correlation between weighted priming scores and word span task in Experiment 2



The correlation between different working memory tasks was also examined. No correlation was found between the scores of the digit and word span tasks (r=-0.028, *p*=0.85), but a correlation was observed between the scores on the forward and backward digit span task (r=0.499, *p*= 3.12e-05). Table 11 shows the correlation matrix of all computed values. These results suggest that working memory is task specific and high score in one domain is not automatically transferable to another. The range of tasks was task specific and perhaps that is why no correlation was found.

Table 11

Correlation matrix for span tasks and priming

	Forward digit span	Backward digit span	Digit spans together	Word span	Weighted priming scores
Forward Digit span	**1.00**	_			
Backward digit span	**0.50**	**1.00**	_		
Digit spans together	**0.83**	**0.90**	**1.00**	_	
Word span	-0.12	0.06	-0.03	**1.00**	_
Weighted priming scores	-0.17	0.09	-0.05	0.02	**1.00**

9. Experiment 3

In the previous two experiments, it was found that there is a structural priming effect in Czech ditransitive sentences. A morphological boost effect, which would strengthen the priming effect by repeating the case endings, was not found. However, the visual representation of the data supports the idea of a morphological boost. The problem may be that not enough sentences with morphological repetition were observed to detect a significant effect. In Experiment 3, a slight change in the experimental paradigm was made to enhance the elicitation of ditransitive structures, which should also have increased the number of sentences with repetition of the case endings.

The initial words of the target sentence were added below the target picture. This sentence contained only the first two words, subject and verb, and participants were asked to complete this sentence according to the picture (a similar experimental paradigm was used by Hartsuiker & Westenberg, 2000). The presented sentence beginning was intended to cue participants to choose a ditransitive construction, but the choice of specific constructions (ACC/DAT or DAT/ACC) was still up to the participant. The sentence presentation was only intended to increase the general number of ditransitive constructions and not the specific ditransitive syntax. The same was true for the morphological boost effect. Even if it increases the number of repetitions of the same case markings, this does not mean that it will artificially increase the number of priming sentences in the same suffix condition. Participants may tend to repeat the suffixes, but they are not boosted to reuse the structure and show the priming effect. The following research question was formulated:

1: How does the repetition of case endings (morphological boost effect) between prime and target nouns affect the structural priming effect in Czech production when forming ditransitive sentence?

9.1 Method

9.1.1 Participants

Similar to the previous experiments, the pool consisted of 64 (58 women) individuals from the LABELS pool, mostly students who received credit for their participation. The average age of the group was 20.4 years (range 18-25 years).

9.1.2 Materials

The stimuli from the second experiment were used again. The only exception was the added hint of the sentence beginning, depicted below the target pictures. The hint always contained the subject of the sentence and a verb followed by an ellipsis. This hint was related to the plot of the picture and the participant had to complete it.

9.1.3 Procedure

The priming procedure was the same picture description paradigm as in the previous experiments. Working memory span tasks were no longer included to measure working memory, as was the case in Experiment 2.

9.1.4 Scoring

Sentences were scored in the same way as in the first experiment. Deverbative adjectives were not included, as was done in Experiment 2.

9.1.5 Analysis

The analysis was the same as in the second experiment. Only the analysis of the priming effect and the morphological boost was performed, not the analysis concerning working memory. The coding scheme was also the same as in Experiment 2.

9.2 Results and discussion

9.2.1 Overall priming effects

A total of 1,536 target sentences were collected from participants. Of this number, 800 were coded as “different structures”, and 736 were coded as ACC/DAT or DAT/ACC structures (Table 12). It appears that the change in design did indeed help to collect more ditransitive constructions. Between Experiments 2 and 3, the number of collected sentences was almost identical, 1,512 and 1,536, respectively. However, after

the addition of the hint words, the number of ditransitive sentences increased from 490 in Experiment 2 to 736 in Experiment 3. The descriptive statistics looks similar to the previous experiments. The target responses after the neutral prime are evenly distributed between the DAT/ACC and ACC/DAT descriptions, but more target responses with the same syntax as the prime were collected in the priming condition (Figure 7).

Table 12

Absolute and relative frequency of responses to target pictures in Experiment 3

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	125	103	0.17	0.14
ACC/ DAT prime	105	143	0.14	0.19
Neutral prime	129	131	0.18	0.18
Together	359	377	0.49	0.51

The first model tested whether there is an overall effect of priming on ditransitive sentences. A significant effect was found for ACC/DAT structures but not for DAT/ACC structures (Table 13), confirming previous observations and providing further evidence for an inverse preference effect. This result was confirmed by an explanatory Anova analysis computed on the GLMM (χ^2 = 13.03, Df = 2, p=0.002).

Table 13

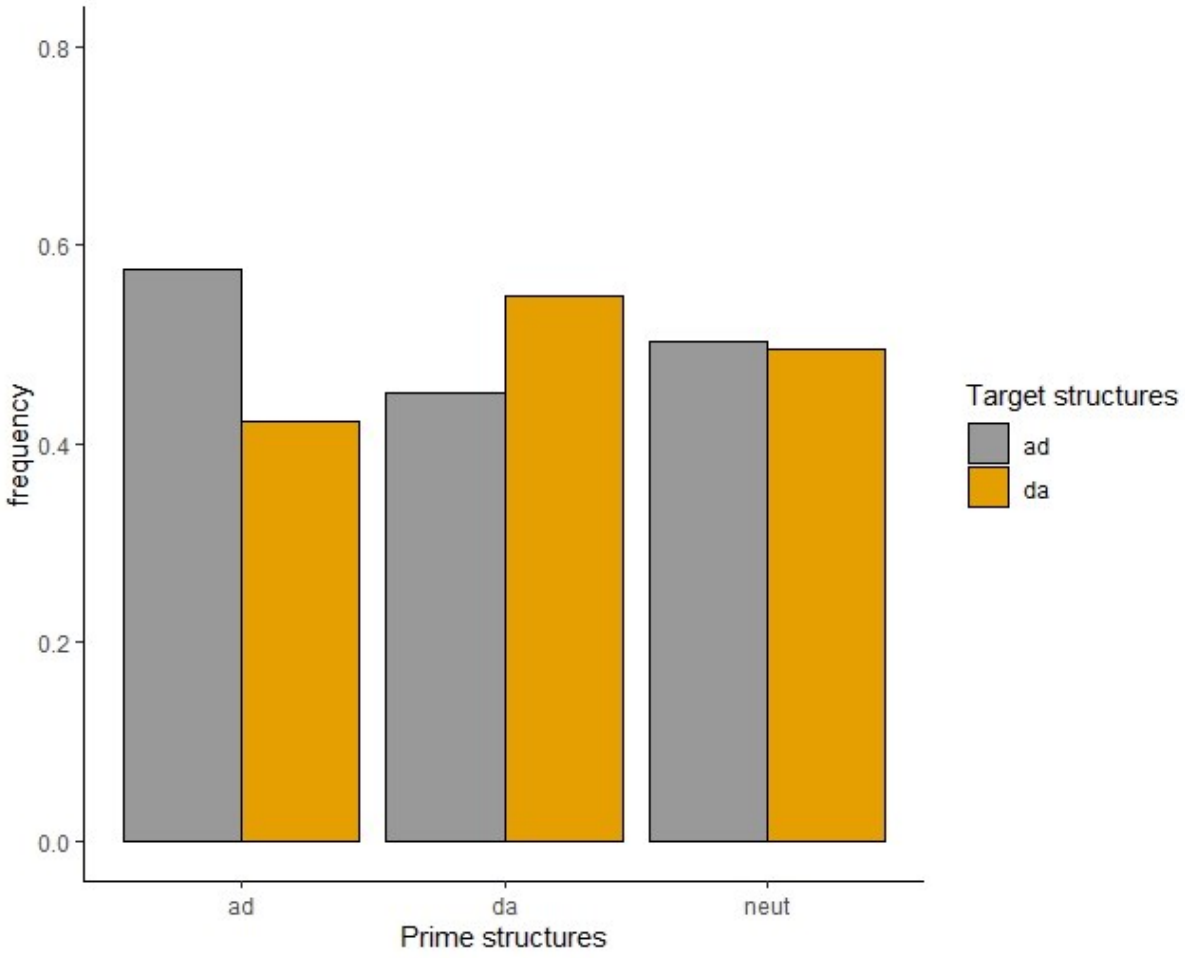
Results model for ditransitive sentences in Experiment 3

Parameter	Estimate	SE	P-value
Intercept	-0.298	0.316	-
Factor DAT/ACC	0.209	0.229	0.360
Factor ACC/DAT	-0.605	0.229	0.008 **

Note. The response variable is target structure.

Figure 7

Relative frequencies for ditransitive primes in Experiment 3



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

9.2.2 Morphological boost effect

The second model focused on the morphological boost effect in the priming of ditransitive sentences. Table 14 shows the absolute frequencies of the target structures produced with repeated suffixes between the prime and target sentences (Same suffix) and in the condition where the suffixes were not repeated (Different suffix). The hint helped to collect more ditransitive responses, especially in the same suffix condition, where there were twice as many as in Experiment 2 (97 versus 193 ditransitive descriptions).

Figure 8 shows the relative frequencies of the target responses. The trend is in favor of priming in all but one condition. The tendency toward priming is not evident after prime DAT/ACC in the condition where the suffixes were not repeated. Again, this is similar to the observations from Experiments 1 and 2, where in the different condition (not repeated verbs – Experiment 1, or not repeated case-ending morphemes – Experiment 2) there was the smallest number of the same repeated structures after the DAT/ACC primes.

Table 14

Absolute frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 3

	Same suffix		Different suffix	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	52	29	73	74
ACC/ DAT prime	53	59	52	84
Together	193		283	

The analysis revealed a significant effect of priming structure ($p > 0.001$) and also an effect of suffix repetition ($p > 0.001$), but the effect of their interaction was not found ($p = 0.638$; Table 15). This is evidence that priming when the case-ending morphemes of nouns are repeated functions differently than when the morphemes are not repeated.

Table 15

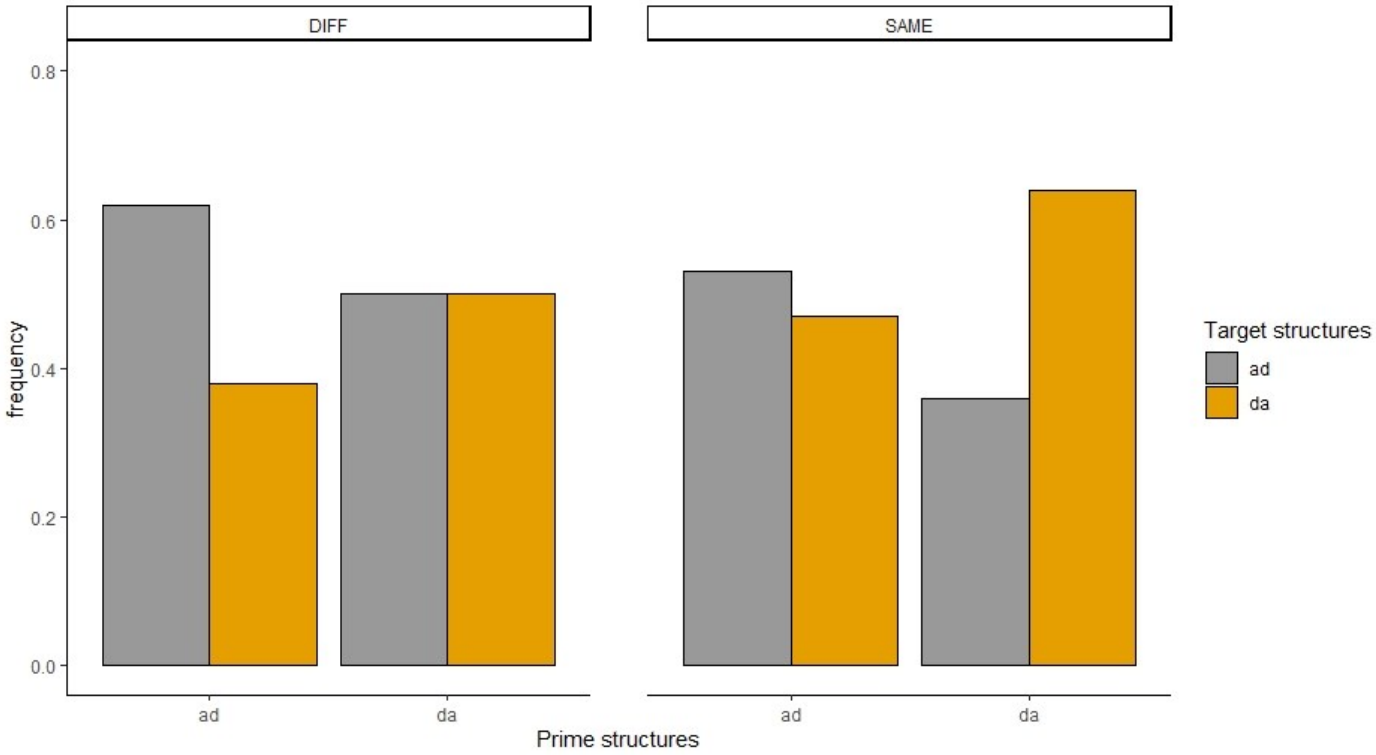
Second results model for ditransitive sentences in Experiment 3

Parameter	Estimate	SE	P-value
Intercept	-0.076	0.215	-
Factor ACC/DAT	-0.396	0.115	0.001 ***
Factor Same	-0.420	0.118	0.001 ***
Interaction Prime type & Suffix repetition	0.054	0.115	0.638

Note. The response variable is target structure.

Figure 8

Relative frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 3



Note. Frequencies are calculated for each prime condition separately. SAME represents condition with repeated morphemes and DIFF represents the condition with unrepeated morphemes. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

10. Experiment 4

Experiment 3 not only proved that there is a structural priming effect in Czech, but also showed that prime-target pairs that do or do not repeat their noun case endings work differently. The design of Experiment 3, however, was constructed so that half of the target pictures were preceded only by a prime sentence with the same case marking endings, and the other half of the target pictures were preceded only by primes that did not share the case-marking morphemes. It is hypothetically possible that some pictures were depicted in a way that predetermined their description by the ditransitive structure more so than with other pictures. If, by chance, more images in either of the two condition groups were affected by this error, it could affect the results.

To solve this issue, another experiment was performed to balance the conditions of the target images. A simple way of balancing the conditions is to add to each target picture a sentence from the second condition. Sentences with different case endings were added before the *same suffix* category pictures, and sentences with the same case endings were added before the *different suffix* category pictures. To make it completely balanced, both ACC/DAT and DAT/ACC structures had to be added, and also one more neutral prime had to be added to make the count fit. In total, there were six versions of the experiment in Experiment 4 as opposed to three in Experiment 3 (Table 16). All other aspects of Experiment 4 were the same as in Experiment 3. As the design was only changed to test whether previous results would be replicated, the research question also remained the same:

1: How does the repetition of case endings (morphological boost effect) between prime and target nouns affect the structural priming effect in Czech production when forming ditransitive sentence?

Table 16

Examples of prime sentences preceding one target picture in different versions in Experiment 4

ACC/DAT prime Same suffix	Inženýr posílá obálk-*u* šéf-*ovi*. (*The engineer sends an envelope to the boss.*)
DAT/ACC prime Same suffix	Inženýr posílá šéf-*ovi* obálk-*u*. (*The engineer sends the boss an envelope.*)
ACC/DAT prime Different suffix	Kluk hlídá dům-0 sestřenic-*i*. (*The boy is house-sitting for his cousin*.)
DAT/ACC prime Different suffix	Kluk hlídá sestřenic-*i* dům-0. (*The boy is house-sitting for his cousin*.)
Neutral prime (2x)	Brouk se usilovně plazil. (*The beetle crawled hard.*)
Possible description of target picture	Hasič zapaluje voják-*ovi* lamp-*u*. (*The fireman lights a lamp for the soldier.*)

10.1 Method

10.1.1 Participants

Participants were again recruited from the LABELS pool, which mostly consists of students who received credits for their participation. First, data were collected from 59 students to match the number of participants from the previous experiments. Later, an additional 40 participants were recruited because of a project involving student practice. The results combine the entire group of 99 participants (76 women), as a larger number of participants should show greater statistical power. The mean age was 22.3 years (range 17-36 years).

10.1.2 Materials

The stimuli were the same as in Experiment 3. The only difference was that each target picture was now preceded (in different versions) by both prime conditions, the one in which the case-marking morphemes were the same and the one in which they

were different (and also a "neutral" condition with an intransitive sentence; see Table 16).

10.1.3 Procedure

The experimental procedure was the same as in Experiment 3.

10.1.4 Scoring

Sentences were scored in the same manner as in Experiment 3.

10.1.5 Analysis

The analysis was the same as in Experiment 3.

10.2 Results and discussion

10.2.1 Overall priming effects

Collected were 2372 target sentences. Of this number, 1185 sentences were coded as ditransitive structures. This number again demonstrates that adding two cue words below the target picture improved the elicitation of ditransitive constructions. From this total number of 1185 ditransitive sentences, 597 sentences with ACC/DAT structures were collected and 590 with the opposite DAT/ACC structures. The number of these two structures is almost identical, but, as in previous experiments, the distribution is in favor of the priming effect (Table 17; Figure 9).

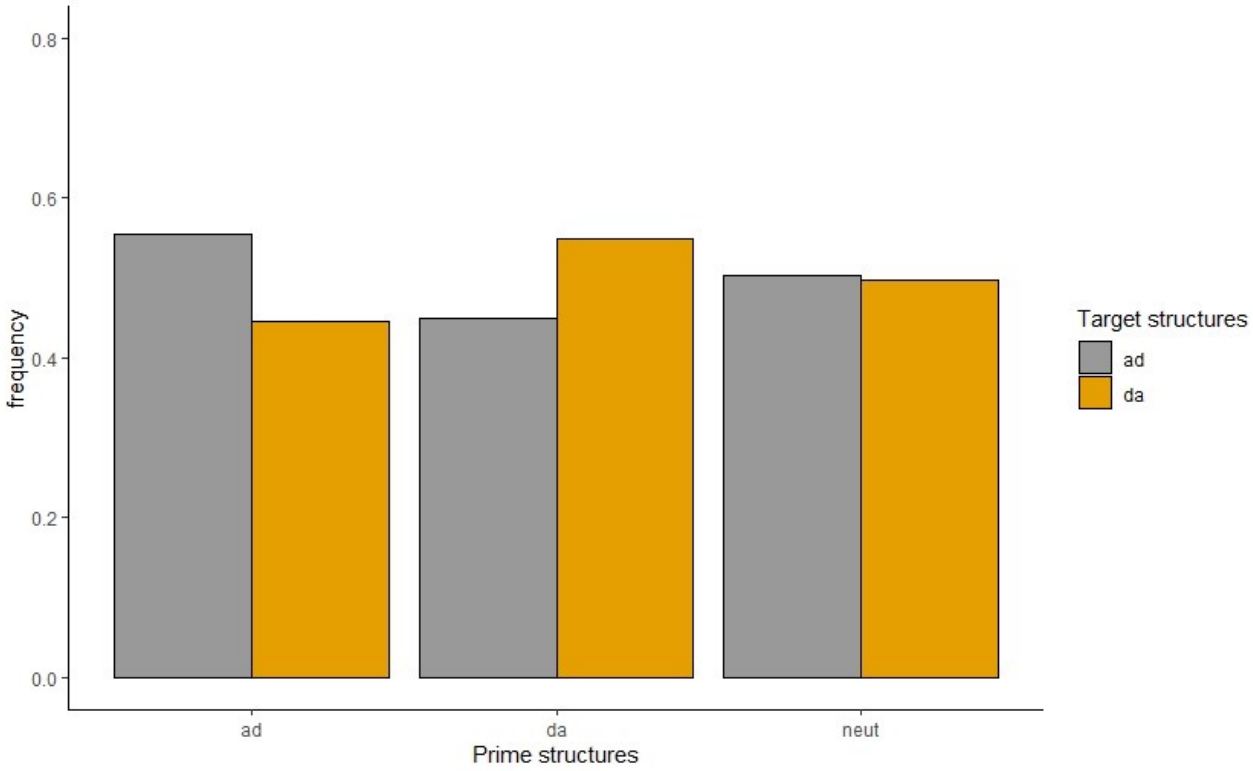
Table 17

Absolute and relative frequency of responses to target pictures in Experiment 4

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	215	176	0.18	0.15
ACC/ DAT prime	182	226	0.16	0.19
Neutral prime	193	195	0.16	0.16
Together	590	597	0.5	0.5

Figure 9

Relative frequencies for ditransitive primes in Experiment 3



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

Table 18

Results model for ditransitive sentences in Experiment 4

Parameter	Estimate	SE	P-value
Intercept	-0.471	0.290	-
Factor DAT/ACC	0.442	0.177	0.013 *
Factor ACC/DAT	-0.240	0.176	0.173

Note. The response variable is target structure.

The first model analyzed whether there is an overall priming effect. The results analysis found only an effect of the DAT/ACC prime structures (p = 0.013) and no effect of ACC/DAT structures (p = 0.173; Table 18). This is in contrast to previous results

where less frequent DAT/ACC structures showed larger effects compared to ACC/DAT structures, suggesting an inverse preference effect. An explanatory Anova analysis performed on the GLMM confirmed this result (χ^2 = 15.18, Df = 2, p = 0.001).

10.2.2 Morphological boost effect

The second model focused on the morphological boost effect. The total number of analyzed sentences was 799, since sentences with a neutral condition again have to be omitted from this analysis, as they do not allow the manipulation of same/different case endings. Of this number, there were 229 targets in which the case-ending morphemes were repeated after a prime (same suffix) and 570 in which the case-ending morphemes were not repeated (different suffix; Table 19). The frequencies of the specific structures produced are consistent with a priming effect. The relative frequencies can be seen in Figure 10.

Table 19

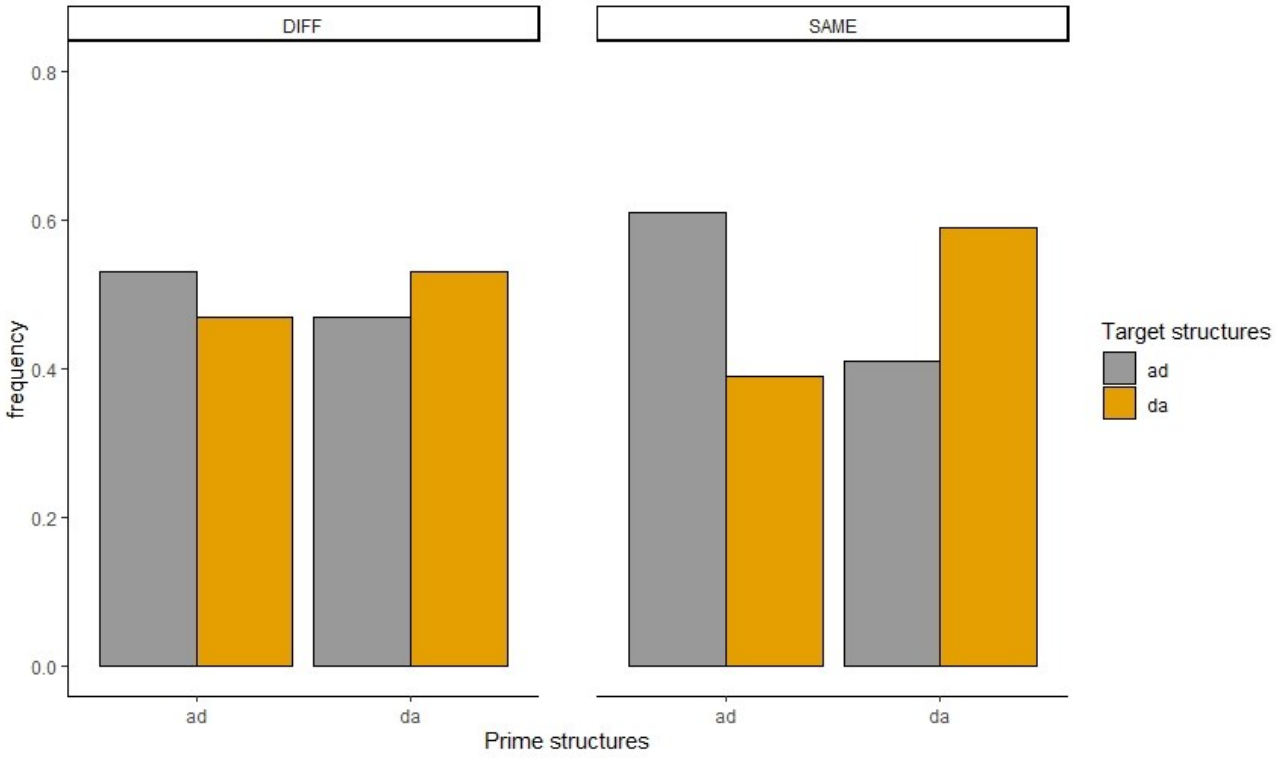
Absolute frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 4

	Same suffix		Different suffix	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	67	46	148	130
ACC/ DAT prime	45	71	137	155
Together	229		570	

GLMM analysis found a significant effect of priming structure (p > 0.001). The effect of suffix repetition was not significant (p = 0.682), and the interaction between prime type and suffix repetition was marginally significant (p = 0.085; Table 20). This suggests the occurrence of morphological boost effect.

Figure 10

Relative frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 4



Note. Frequencies are calculated for each prime condition separately. SAME represents condition with repeated morphemes and DIFF represents the condition with unrepeated morphemes. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

Table 20

Second results model for ditransitive sentences in Experiment 4

Parameter	Estimate	SE	P-value
Intercept	-0.337	0.303	-
Factor ACC/DAT	-0.425	0.102	3.07e-05 ***
Factor Different	-0.044	0.108	0.682
Interaction Prime Type & Suffix repetition	0.176	0.102	0.085 .

Note. The response variable is target structure.

11. Experiment 5

Experiment 4 pointed to the fact that there could be a morphological boost effect. Although the interaction between the factor *structure type* and the factor *repetition of the case-ending suffix* was only marginally significant, taken together with the descriptive statistics, it suggests that the repetition of the endings may enhance the priming effect. Another question that arises is whether all case-ending morphemes act with the same strength. For example, most of the case endings are only single-letter syllables (*-e*, *-u*), but some are longer (*-ovi*). Longer case endings may be more salient in language processing and thus may produce a greater boost effect in priming. This may be one reason why robust effects were not found; some of the case-ending morphemes may have less of an effect. Experiment 5 focuses on the question of whether different suffixes may affect the priming effect to varying degrees.

In Experiments 2, 3, and 4, two different types of dative case-ending morphemes were used in the *same* condition (where suffixes could be repeated between the prime and the target): the longer suffix *-ovi* for masculine nouns and the shorter suffix *-e* for feminine nouns. Nouns ending in the accusative case in *same* condition always had the suffix *-u*. In the *different* condition, where the repetition of suffixes between sentences was diminished, different types of suffixes were used – for nouns in the dative case it could be *-ovi*, *-e, -i,* and in the accusative case it could be *-u, -i* or a zero- marked suffix. It was random which one was used as long as the suffixes differed between the prime and target. Unfortunately, the designs of these experiments did not allow for adequate comparison of the effect of different types of suffixes.

In the present experiment, the design was changed so that different suffixes could be compared. The focus was on the two previously used dative suffixes *-ovi* and *-u.* These suffixes were used because of their different lengths. The expectation was that longer suffixes could have a greater effect on structural priming than shorter ones. The accusative suffix was always set to be *-u* in order to make the conditions during comparison of dative suffixes comparable. The target picture was depicted so that the description would trigger a dative construction with nouns ending in the suffix *-ovi* when preceded by a prime sentence with the suffix *-ovi* in the same condition, and with the suffix *-e* in a different condition. For target sentences with a dative noun ending with *-u*, it was the other way around, they were preceded in the same condition by a prime

noun ending with *-u*, and in the different condition by a prime noun ending with *-ovi.* Both target sentences could also be preceded by a neutral non-ditransitive sentence (Table 21).

Table 21

Examples of prime sentences in Experiment 5

	Prime Same suffix	Prime Different suffix	Prime Neutral condition
Target picture "-e" Rytíř dává princezn-*ě* knih-*u*. (The knight gives the princess a book.)	Kráva olizuje ovečc-*e* hlav-*u*. (A cow licks a sheep's head.)	Babička čte vnuk-*ovi* pohádk-*u*. (A grandmother reads a story to her grandson.)	Právník po ránu snídá. (A lawyer eats breakfast in the morning.)
Target picture "-ovi" Zmrzlinář prodává námořník-*ovi* zmrzlin-*u*. (An ice cream man sells ice cream to a sailor.)	Vlčák kouše pytlák-*ovi* pušk-*u*. (A wolf bites a poacher's rifle.)	Ředitel podpisuje referent-*e* smlouv-*u*. (The director signs the contract for the clerk.)	Kapelník hraje na kytaru. (The bandleader plays guitar.)

As the experiment took place during the Covid pandemic, the testing was conducted online. This meant that the procedure had to be slightly altered to make it suitable for online testing (more in section 11.1.3), but in general the task remained the same as in Experiment 4. For Experiment 5, the following research questions were formulated:

1: How does the repetition of case endings (morphological boost effect) between prime and target nouns affect the structural priming effect in Czech production in an online environment when forming ditransitive sentence?

2: Do different case-ending suffixes of nouns increase the structural priming effect to different degrees?

11.1 Method

11.1.1 Participants

The experiment involved 60 people (46 women) from LABELS pool, which mainly consists of students who received credit for their attendance. The average age of the group was 21.2 years (range 19-41 years).

11.1.2 Materials

The stimuli were similar to those in Experiment 4. Some of the prime sentences were changed to match the *-ovi/-e* suffixes, but all target pictures remained the same.

11.1.3 Procedure

The overall testing procedure remained the same as in Experiment 4, but was applied to the online condition. Participants were emailed instructions and an invitation link to attend a Zoom session with an administrator. Stimuli were presented to participants on-screen via Zoom. The only other significant difference was that the procedure was not self-paced, but was paced by the administrator after the participant read a sentence or described a picture.

11.1.4 Scoring

Sentences were scored in the same manner as in Experiment 4. Although the experiment focused on the dative suffixes *-ovi* and *-e*, participants still had to also repeat the accusative suffix *-u* in order for the sentence to be scored as the same condition.

11.1.5 Analysis

The analysis was the same as in Experiment 4, but three models were tested. The first two models were the same as in the previous experiment, and the third model analyzed the effect of individual suffixes (*-ovi* vs *-e*). The fixed effects in the third model were sum coded and contained Prime type (AD coded as 1 and DA as -1) and the Type of repeated morpheme (*-e* coded as 1 and *-ovi* as -1) and their interaction.

11.2 Results and discussion

11.2.1 Overall priming effects

A total of 1421 target descriptions were collected, and of this number, 598 were ditransitive target descriptions. There were slightly more ACC/DAT constructions than DAT/ACC constructions, 314 and 284 respectively (Table 22). The distribution is similar to the previous experiments in favor of a priming effect. Figure 11 shows the relative frequency of structures.

Table 22

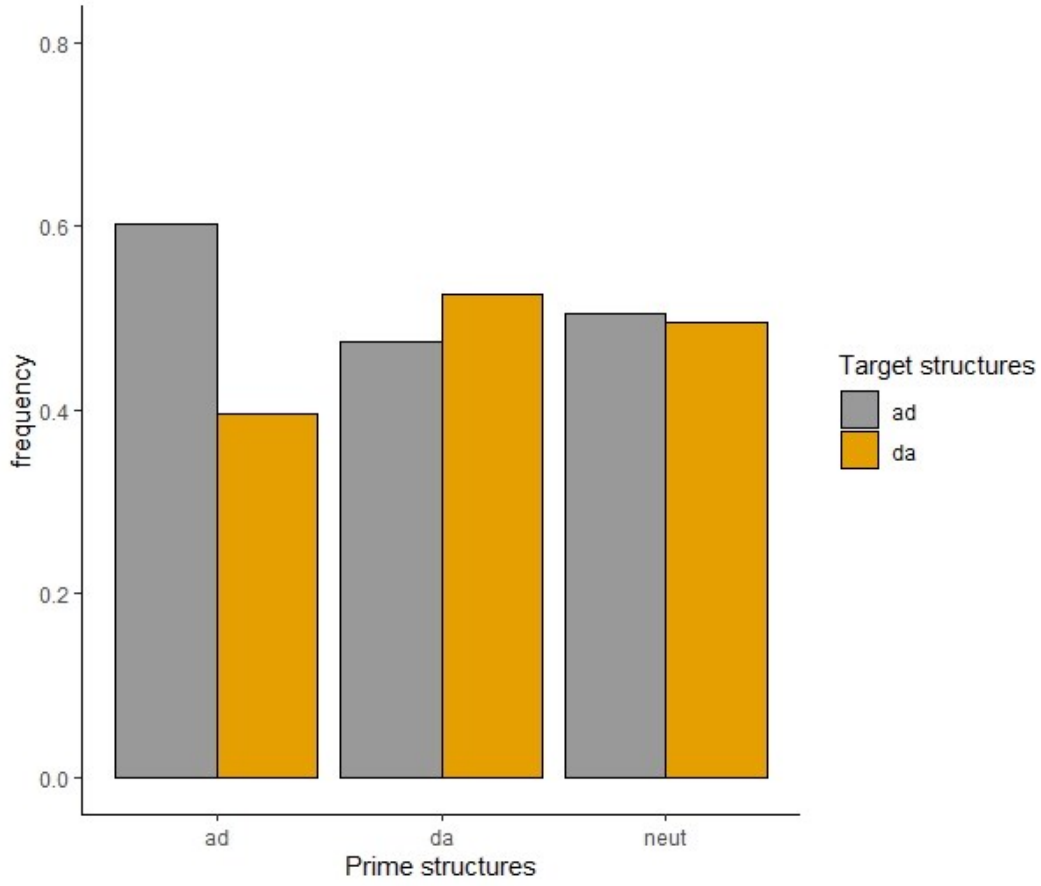
Absolute and relative frequency of responses to target pictures in Experiment 5

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	109	98	0.18	0.16
ACC/ DAT prime	75	114	0.13	0.19
Neutral prime	100	102	0.17	0.17
Together	284	314	0.48	0.52

The GLMM found only a weak effect of ACC/DAT prime structures (p = 0.063) and no effect of DAT/ACC structures (p = 0.547; Table 23). This is consistent with previous results, where less frequent ACC/DAT structures showed larger effects, suggesting an inverse preference effect. The effect was only marginally significant, but the Anova analysis computed on the GLMM showed priming trend (χ^2 = 13.03, Df = 2, p=0.002). The difference in significance between the GLMM and Anova could be explained by the fact that the GLMM focuses on individual fixed effects, but Anova tests the overall effect of each fixed effect.

Figure 11

Relative frequencies for ditransitive primes after different primes in Experiment 5



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

Table 23

Results model for ditransitive sentences in Experiment 5

Parameter	Estimate	SE	P-value
Intercept	-0.174	0.253	-
Factor DAT/ACC	0.153	0.253	0.547
Factor ACC/DAT	-0.483	0.260	0.063 .

Note. The response variable is target structure.

11.2.2 Morphological boost effect

The second model focused on the effect of morphological boost. Three hundred and ninety-six sentences were analyzed, and of this number, 106 sentences were in the same suffix condition and 290 were in the different suffix condition (Table 24). The Figure 12 shows the relative frequencies of the collected structures. From this figure, it can be seen that the data from the different suffix condition are consistent with a priming effect. On the other hand, this is not the case for the same suffix condition, where only ACC/DAT structures show a priming trend. DAT/ACC primes in the same condition produced the same number of DAT/ACC descriptions as ACC/DAT descriptions. However, this does not necessarily mean that there is no priming effect; it may only indicate that not enough sentences were collected for the effect to show up. The effect is visible for ACC/DAT structures, perhaps because they are less prominent in the language and are likely to be reinforced by the inverse preference effect.

Table 24

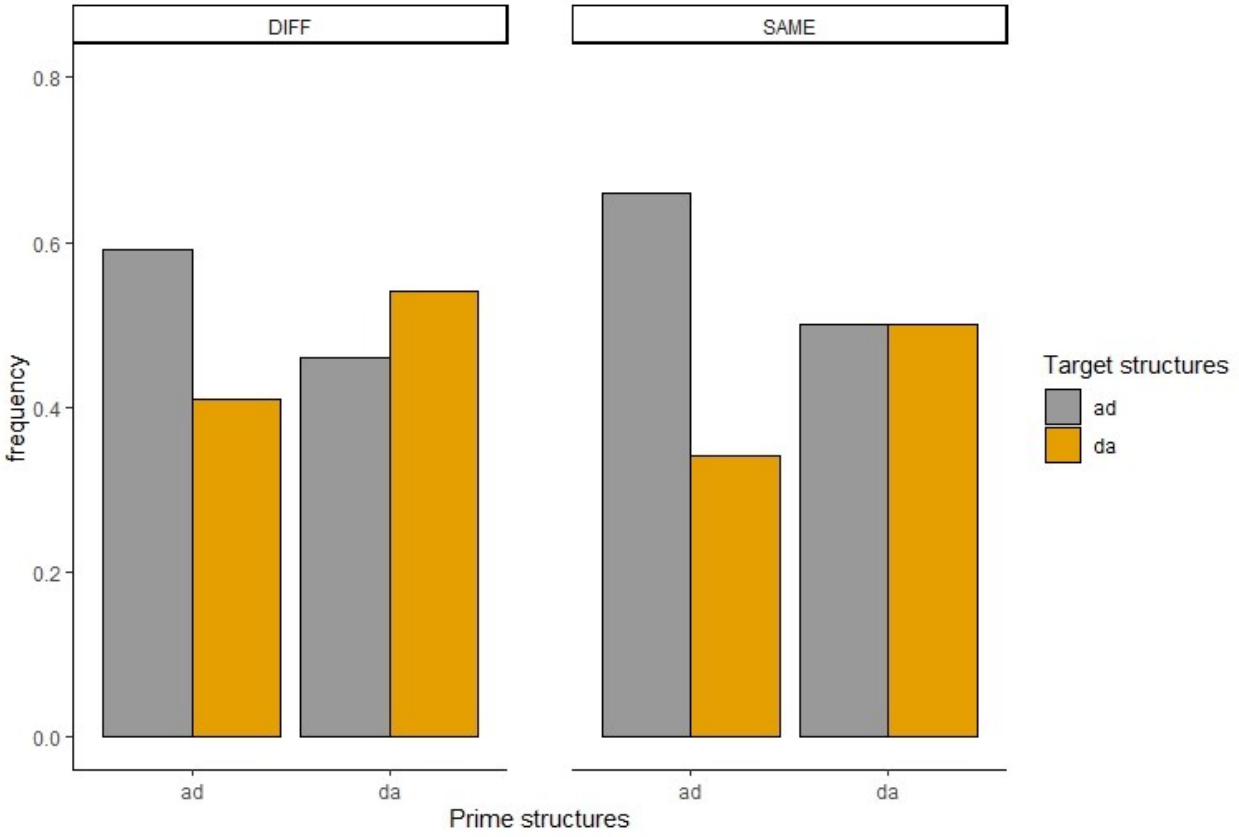
Absolute frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 5

	Same suffix		Different suffix	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	28	28	81	70
ACC/ DAT prime	17	33	58	81
Together	106		290	

The GLMM found a significant effect only for the priming structure (p = 0.016). The effect of suffix repetition was not statistically significant (p = 0.328), nor was the interaction between prime type and suffix repetition (p = 0.606; Table 25). This does not support the findings of Experiment 4, which suggested the morphological boost effect.

Figure 12

Relative frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 5



Note. Frequencies are calculated for each prime condition separately. SAME represents condition with repeated morphemes and DIFF represents the condition with unrepeated morphemes. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

Table 25

Second results model for ditransitive sentences in Experiment 5

Parameter	Estimate	SE	P-value
Intercept	-0.384	0.315	-
Factor ACC/DAT	-0.359	0.150	0.016 *
Factor Different	0.157	0.161	0.328
Interaction Prime type & Suffix repetition	0.077	0.149	0.606

Note. The response variable is target structure.

11.2.3 Effect of suffix type

The third analysis was interested in the effect of a particular type of suffix. Two dative case-ending suffixes, *-ovi* and *-e,* were used, and it was hypothesized that the longer ending *-ovi* would have a greater boost effect than the shorter *-e* ending.

Table 26 shows the frequencies of sentences in which the case endings *-ovi* or *-e* were used in the same suffix condition. Of the 106 sentences in which the suffixes were repeated, 42 were sentences with the suffix *-ovi,* and 64 were sentences with the suffix *-e.* Their relative frequencies can be seen in Figure 13. A tendency to priming is present after all primes except the DAT/ACC primes in the *-ovi* condition. This is rather unexpected, as the longer form *-ovi* was expected to increase the priming effect. However, this discrepancy may have been due to the insufficient number of target sentences in this condition. Only 20 target sentences with DAT/ACC structure were produced in the *-ovi* condition, which might have been too few to detect a priming effect. The most pronounced priming effect appeared after the ACC/DAT prime structures in both suffix conditions, which is further evidence of the inverse preference effect. Also interesting is the fact that people in general repeated more sentences with the ending *-e* than the sentences with longer ending *-ovi*.

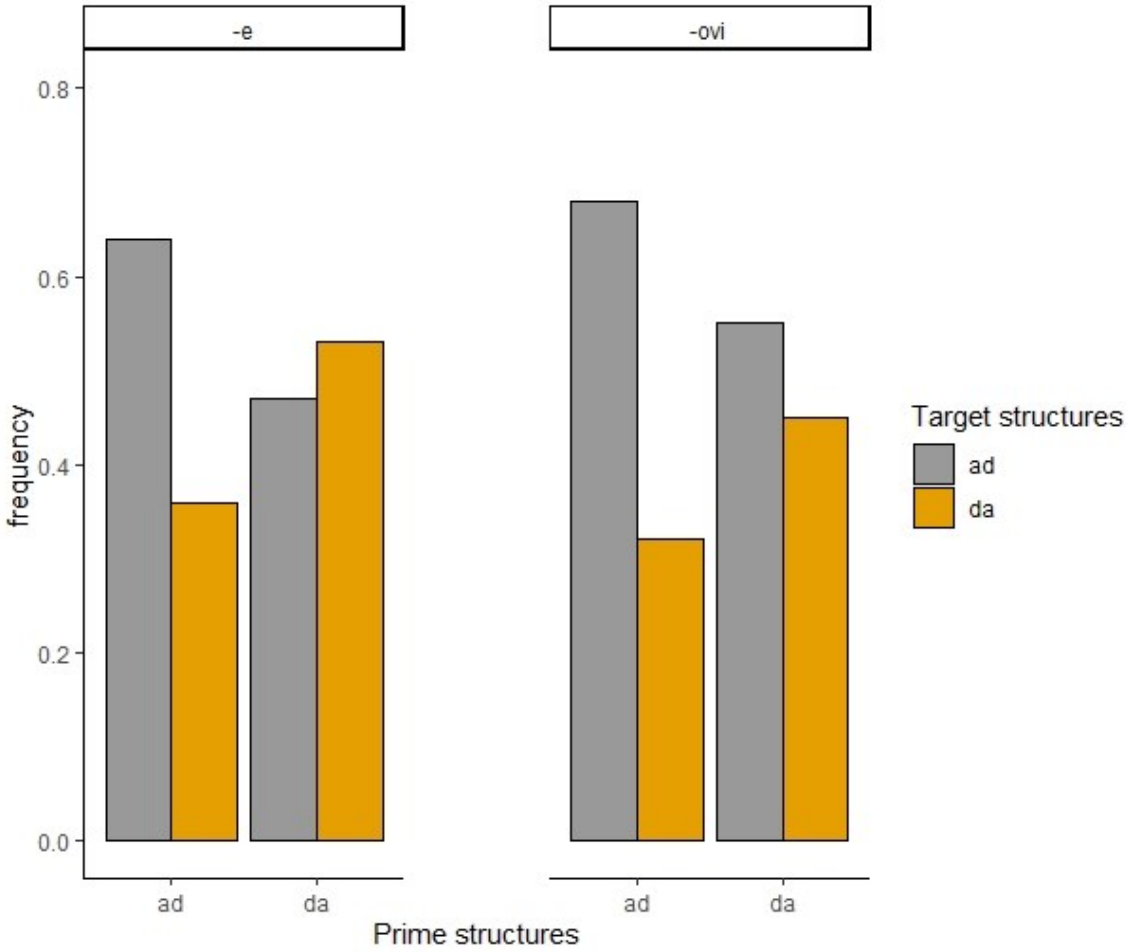
Table 26

Absolute frequencies of targets following prime sentences in conditions with dative ending -ovi or -e in same suffix condition in Experiment 5

	Suffix -ovi		Suffix -e	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	9	11	19	17
ACC/ DAT prime	7	15	10	18
Together	42		64	

Figure 13

Relative frequencies of targets following prime sentences in conditions with dative ending -ovi *or* -e *in same suffix condition in Experiment 5*



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

The GLMM shows only a marginally significant effect of prime structure (p = 0.069). Neither the effect of the suffix type (p = 0.760) nor the interaction between priming type and suffix type were significant (Table 27). The previous model suggests that prime structure had a greater effect. That may be evidence that subtracting the data into smaller elements reduces statistical power and makes it more difficult to detect a priming effect. It is possible that a much larger dataset is needed to satisfactorily detect morphological boost or the effect of a particular suffix type. Thus, Experiment 5 does not provide evidence that different suffixes increase structural priming to different degrees.

Table 27

Third results model for ditransitive sentences in Experiment 5

Parameter	Estimate	SE	P-value
Intercept	-0.401	0.618	-
Factor ACC/DAT	-0.213	0.666	0.069 .
Factor -ovi	0.138	0.453	0.760
Interaction Prime type & Suffix type	-0.158	0.630	0.802

Note. The response variable is target structure.

12. Experiment 6

Experiment 5 did not provide evidence that different case-ending morphemes can amplify the priming effect through a morphological boost to varying degrees depending on the suffix type. Nor did it support the findings of Experiment 4, which suggested that a morphological boost occurs. The observed structural priming effect in online Experiment 5 was also weaker than in previous laboratory experiments. Overall, it appears that the priming effect was generally too weak to be sufficiently detected.

Interactive alignment theory (Pickering & Garrod, 2004) argues that structural priming serves a social purpose, where two people align their formulations in order to make their communication more effective. The online settings of Experiment 5 might reduce this alignment aspect, and participants might perceive the situation as less social than the testing situation in the laboratory. This could explain why the tendency to priming was reduced in Experiment 5.

After restrictive Coronavirus measures were lifted, a new Experiment 6 was conducted under laboratory conditions to test the reliability of Experiment 5. It had exactly the same design and stimuli as online Experiment 5. The research questions formulated were almost identical to those in the previous experiment:

1: How does the repetition of case endings (morphological boost effect) between prime and target nouns affect the structural priming effect in Czech production when forming ditransitive sentence?

2: Do different noun suffixes increase the structural priming effect to different degrees?

12.1 Method

12.1.1 Participants

Also in this experiment, participants were recruited from LABELS pool. They were mainly students, who received credit for their participation. The total number of participants was 61 people (52 women). The average age was 21.5 years (range 19-34).

12.1.2 Materials

The stimuli were the same as in Experiment 5.

12.1.3 Procedure

Since the Covid restrictions had been lifted, the experimental procedure was the same as in laboratory Experiment 4. The experiment was conducted in the lab, and this is the only difference between the previous online Experiment 5 and the Experiment 6.

12.1.4 Scoring

Sentences were scored in the same way as in Experiment 5.

12.1.5 Analysis

The analysis was identical to that of Experiment 5.

12.2 Results and discussion

12.2.1 Overall priming effects

The number of collected target sentences was 1406, almost the same number as in online Experiment 5 (1421). However, the number of ditransitive target sentences analyzed was 695, almost 100 ditransitive target sentences more than in online Experiment 5 (598). This suggests that the laboratory situation may yield larger priming effects. The number of DAT/ACC and ACC/DAT structures collected was fairly balanced, with frequencies in favor of a priming effect (Table 28). After the neutral condition, people described the picture slightly more frequently with the DAT/ACC form, which was not observed in previous experiments. Figure 14 shows the relative frequencies of the ditransitive structures described.

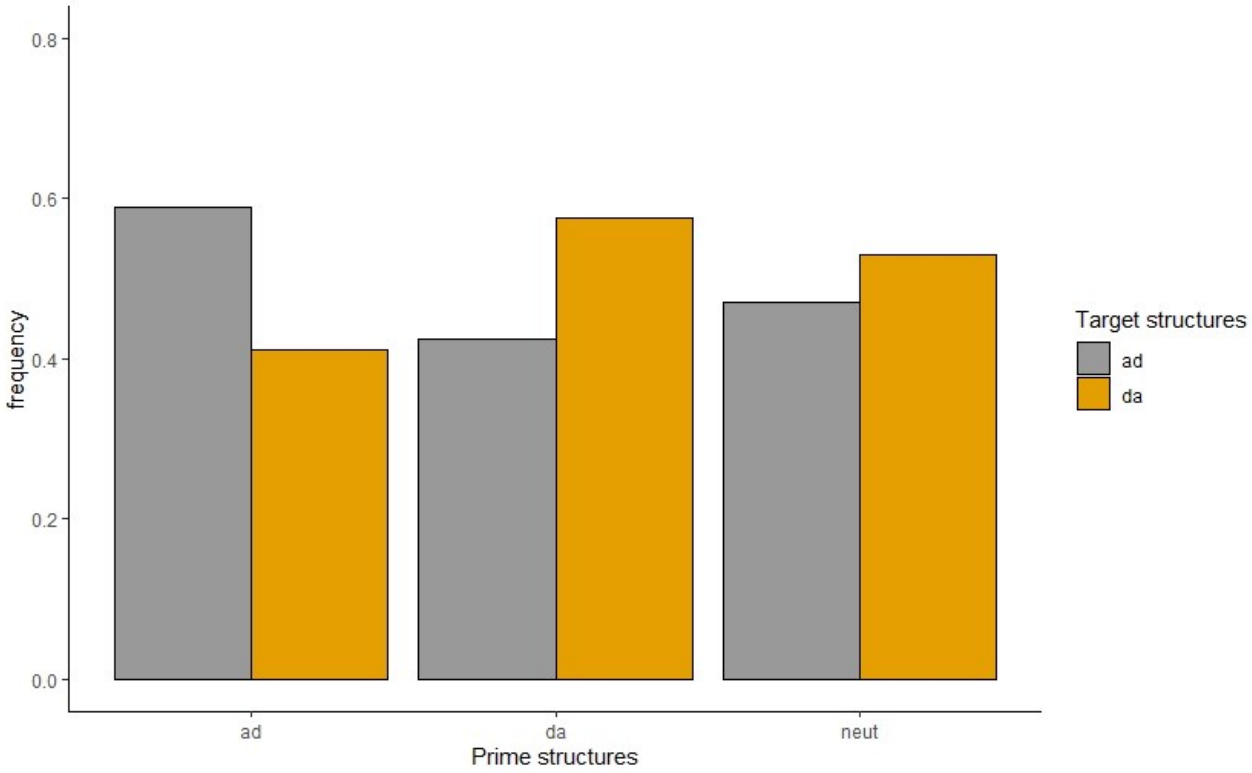
Table 28

Absolute and relative frequency of responses target pictures in Experiment 6

	Absolute		Relative	
	DAT/ACC target	ACC/DAT target	DAT/ACC target	ACC/DAT target
DAT/ACC prime	138	102	0.20	0.15
ACC/ DAT prime	91	130	0.13	0.19
Neutral prime	124	110	0.18	0.16
Together	353	342	0.51	0.5

Figure 14

Relative frequencies for ditransitive primes after different primes in Experiment 6



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

The first model found a significant difference between the effects of the ACC/DAT prime and the baseline condition (p = 0.045), and a marginally significant difference between the DAT/ACC structure and baseline (p = 0.09; Table 29). Consistent with previous experiments, this again confirms an inverse preference effect for structural priming. An explanatory Anova analysis conducted on the GLMM supported the result (χ^2 = 13.44, Df = 2, p=0.001).

Table 29

Results model for ditransitive sentences in Experiment 6

Parameter	Estimate	SE	P-value
Intercept	-0.286	0.376	-
Factor DAT/ACC	0.414	0.243	0.090 .
Factor ACC/DAT	-0.498	0.249	0.045 *

Note. The response variable is target structure.

12.2.2 Morphological boost effect

Of the 461 analyzed sentences, 134 were in the same suffix condition and 327 were in the different suffix condition (Table 30), both categories indicating the presence of a priming effect (Figure 15). In the second model, only the effect of priming structure was statistically significant ($p > 0.001$). The effect of suffix repetition ($p = 0.234$) and its interaction with priming structure showed no significant effects (p = 0.923; Table 31).

Table 30

Absolute frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 6

	Same suffix		Different suffix	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	44	27	94	75
ACC/ DAT prime	27	36	64	94
Together	134		327	

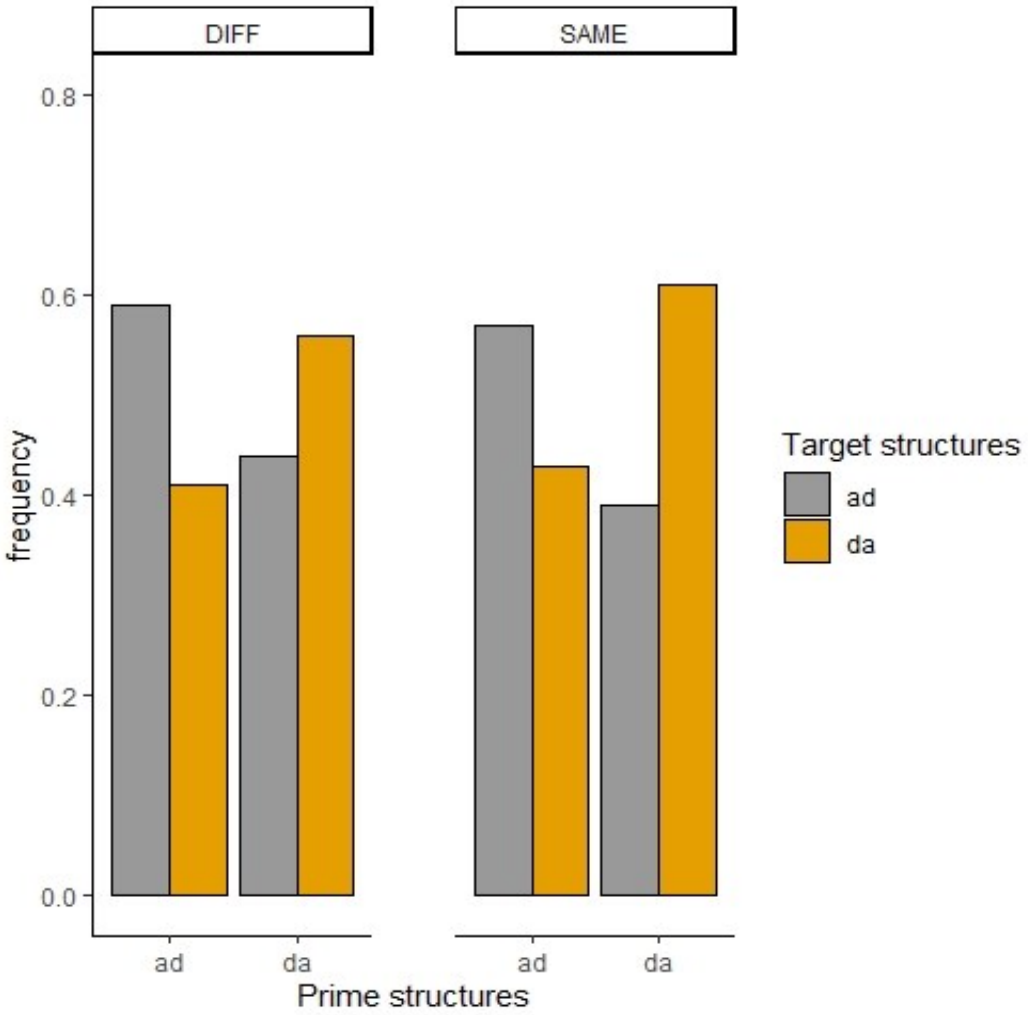
Table 31

Second results model for ditransitive sentences in Experiment 6

Parameter	Estimate	SE	P-value
Intercept	-0.295	0.404	-
Factor AD	-0.512	0.150	0.001 ***
Factor Different	-0.188	0.159	0.234
Interaction Prime type & Suffix repetition	0.014	0.149	0.923

Figure 15

Relative frequencies of targets following prime sentences in conditions with repeated or unrepeated case ending morphemes in Experiment 6



Note. Frequencies are calculated for each prime condition separately. SAME represents condition with repeated morphemes and DIFF represents the condition with unrepeated morphemes. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

12.2.3 Effect of suffix type

The third analysis examined the effect of specific case-ending morphemes. Two different endings, one longer (*-ovi*) and one shorter (*-e*), were used in the dative case of nouns. It was hypothesized that the longer version would be more prominent, and thus its repetition would boost the priming effect more. Of all the structures with repeated suffixes (134), 58 sentences were with the suffix *-ovi* and 76 with the suffix *-e* (Table 32).

As shown in the previous analysis, there are slightly more structures in the same suffix condition than there were in online Experiment 5 (132 vs 106). A visual representation of their relative frequencies (Figure 16) shows that priming is more pronounced in the *-ovi* condition, although fewer sentences were produced in this category. In the *-e* suffix condition, priming occurs only in the DAT/ACC structure, a curious observation as this contradicts the otherwise apparent inverse preference effect.

Table 32

Absolute frequencies of targets following prime sentences in conditions with dative ending -ovi or -e in same suffix condition in Experiment 6

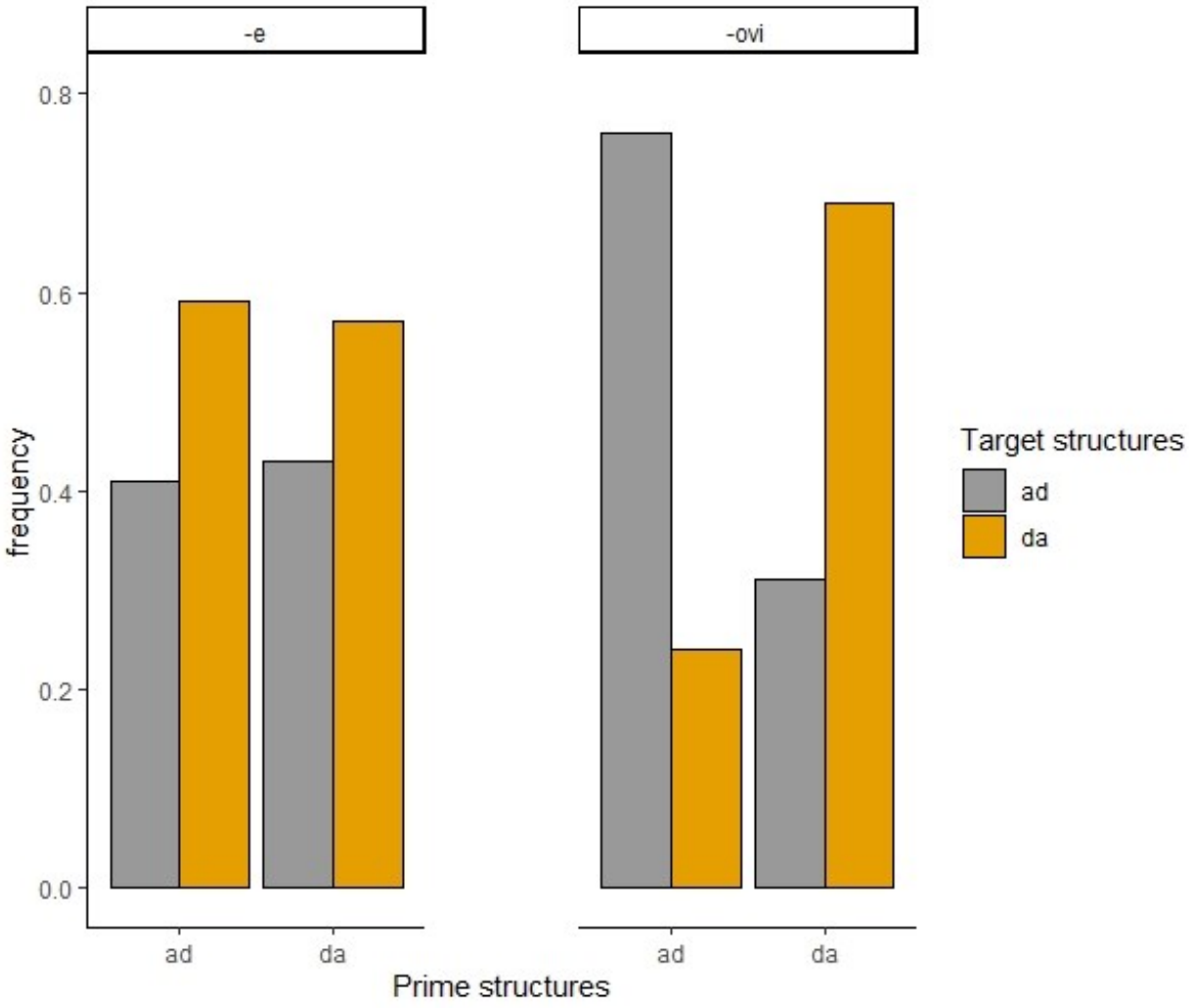
	Suffix -ovi		Suffix -e	
	DAT/ACC	ACC/DAT	DAT/ACC	ACC/DAT
DAT/ACC prime	20	9	24	18
ACC/ DAT prime	7	22	20	14
Together	58		76	

Results of the model show an effect of priming structure (p = 0.016) but not an effect of suffix type (p = 0.374; Table 33). The interaction between priming structure and suffix type was significant (p = 0.014). This points to the conclusion that priming works differently between a sentence in which the suffix *-ovi* or suffix *-e* is repeated, but it depends on the structure type.

The priming effect in the *-ovi* condition is evident from Figure 16. For the *-e* condition, no differences are seen between the two structures, indicating no or weak priming effect. There are more DAT/ACC targets after the DAT/ACC primes, but also after the ACC/DAT primes. This may reflect a natural tendency to produce more DAT/ACC ditransitive structures in general. Otherwise, the inverse preference effect would suggest that the priming effect should be larger for the opposite ACC/DAT structure, as seen in previous experiments. Although there may be a weak priming effect for the DAT/ACC structures in the *-e* condition, in the *-ovi* condition this effect is much larger and visible for both ditransitive structures used (Figure 16).

Figure 16

Relative frequencies of targets following prime sentences in conditions with dative ending -ovi or -e in same suffix condition in Experiment 6



Note. Frequencies are calculated for each prime condition separately. Shortcuts represent ditransitive accusative/dative structure (ad) or ditransitive dative/accusative structure (da).

This means that the suffix *-ovi* has a greater morphological boost effect than its shorter counterpart *-e*, which is reflected in the results of the analysis. The priming tendency in the same condition, as shown in Figure 15, is driven by sentences with the suffix *-ovi*. This also explains why there is a larger effect in the DAT/ACC structures, because there was a priming tendency for both suffixes, *-ovi* and *-e.* The fact that the priming tendency for the *-ovi* condition is present in only 58 sentences compared to 76

sentences in the *-e* condition provides further evidence that the morphological effect is indeed pronounced for the longer *-ovi* case endings.

Table 33

Third results model for ditransitive sentences in Experiment 6

Parameter	Estimate	SE	P-value
Intercept	0.604	0.327	-
Factor AD	-1.059	0.438	0.016 *
Factor -ovi	-0.263	0.297	0.374
Interaction Prime type & Suffix type	1.082	0.438	0.014 *

Note. The response variable is target structure.

13. General discussion

The general aim of this thesis was to determine whether there is a structural priming effect in Czech, a phenomenon that is also strongly manifested in other studied languages. The picture description paradigm, which has been frequently and successfully used since the beginning of structural priming studies (Bock, 1986; Bock and Loebell, 1990; Ziegler et al., 2019), was used for the research.

Transitive OVS and SVO structures (Sentences 1 and 2) and ditransitive structures with alternating direct and indirect objects (Sentences 3 and 4) were used to test the priming effect. The main hypothesis was confirmed; however, the structural priming effect was only observed in ditransitive sentences. Spontaneous OVS production was minimal regardless of primes.

1. SVO structure: Koza žrala trávu na louce. (ENG: *A goat was eating grass in a meadow*.)
2. OVS structure: Trávu žrala koza na louce. (ENG: *The grass was eaten by a goat in a meadow.*)
3. DAT/ACC structure: Veterinářka stříhá psovi drápy. (ENG: *A vet is clipping the dog's claws.*)
4. ACC/DAT structure: Veterinářka stříhá drápy psovi. (ENG: *The vet is clipping the claws of the dog.*)

In total, six different experiments were conducted. They differed slightly in their design and specific focus. Table 34 presents their differences and research interests. In the later series of experiments (from Experiment 3 onwards), two hint words were added below the target images. Their role was to guide participants in the production of the transitive sentence, as there was a concern that the number of structures produced in the condition where the suffixes are repeated might not be sufficient to capture the morphological boost effect.

Unlike all of the other experiments, Experiment 5 was conducted online during the Covid pandemic and not in a laboratory (see Table 34). This made it possible to compare the online testing with the laboratory experiments where there was more social interaction.

In addition to identifying the effect of priming in Czech, this thesis also focused on several effects that may play a role in the functioning of priming. Two different boosting effects which should enhance priming were tested. The first is the lexical boost effect, which stems from the lexical level and is well known in the literature. The second enhancing effect occurs at the morphological level. It is referred to as the morphological boost effect in this thesis and is not yet well described. Previous studies that have focused on the morphological effect have examined languages from different language families and found conflicting results – Basque has not confirmed the morphological effect (Santesteban et al., 2015), but Korean has (Chung and Lee, 2017). The influence of working memory on priming was another effect that was investigated. The results and their implications are discussed in more detail in the following subsections.

Table 34

Main differences between conducted experiments

	Investigated boost effect	Environment	Used hint words	Other investigated effects
Experiment 1	lexical	laboratory	-	SVO/OVS structure priming
Experiment 2	morphological	laboratory	-	working memory
Experiment 3	morphological	laboratory	yes	-
Experiment 4	morphological	laboratory	yes	-
Experiment 5	morphological	online	yes	suffix type (-e vs -ovi)
Experiment 6	morphological	laboratory	yes	suffix type (-e vs -ovi)

13.1 Overall priming tendencies

This thesis tried to replicate the basic priming results achieved by Bock (1986). However, due to the differences between English and Czech, it was not possible to test the exact same linguistic structures.

Thus, the first constructions used were transitive SVO and OVS sentences. Although the previously used passive voice is not as common in Czech as in English, the OVS construction emphasizes the object of the transitive action in a similar way to the passive voice. Contrary to expectations, Experiment 1 showed that people hardly repeat OVS structures at all. Of the 604 transitive target descriptions collected, only 9 had an OVS structure (Table 2). This might be due to the fact that OVS sentences have the same

information structure as SVO sentences but opposite structure of syntactic roles. The focus of the OVS structure on the object may sound strange if it is not accompanied by context. In this case, people do not find this syntax acceptable and do not produce these constructions when they do not need to emphasize the object. Due to the lack of priming effects found with this construction, structures with SVO/OVS alternation were omitted from further experiments.

The other type of structure used were ditransitive sentences. However, Czech, unlike English, is not dependent on prepositional phrases, and therefore alternation was expressed by changing the order of the direct and indirect object (Sentences 3 and 4). For these constructions, a priming effect was detected, thus confirming a structural priming effect for Czech.

Statistical analysis confirmed a priming effect in all six experiments, but in the online experiment (Experiment 5) the priming effect was only marginally significant (p = 0.063). The difference between the online and laboratory experiments is described more extensively in the following section (13.2 Social factors and alignment in priming). Figure 17 shows the priming tendencies for the ACC/DAT structures during the experiments. It can be seen that the number of ACC/DAT structures after the neutral condition is approximately 50%, but proportionally more ACC/DAT structures are produced after the ACC/DAT primes and the opposite is true for the DAT/ACC primes. This is a visually descriptive confirmation of the priming effect.

Table 35 numerically summarizes the overall priming tendencies in all of the experiments. On average, 57% of all ditransitive structures produced were primed (ranging from 61% in Experiment 1 to 55% in Experiment 4). ACC/DAT structures were primed to a greater extent than the opposite DAT/ACC structures in five of the six experiments. Given that the ACC/DAT syntax is less frequent in Czech, this confirms the inverse preference effect where less frequent structures elicit a stronger effect (Bock & Griffin, 2000; Ferreira & Bock, 2006, Segaert et al., 2011). The inverse preference effect was observed everywhere but in Experiment 4, where the smallest percentage of sentences (55%) were primed, which may be why the effect did not occur.

What specifically was primed in the experiments? Was it the abstract constituent structure or another linguistic level, such as the structure of thematic roles? As discussed in Chapter 3, distinguishing between different sources of structural priming is difficult. Of course, the first obvious possibility is that the abstract constituent structure

was primed. The abstract tree structure was repeated across sentences, but the observed priming could have been driven by another overlapping linguistic level. Ditransitive sentences, in which the differences between alternating constructions are expressed only by the word order of the direct and indirect object, were primed. When after the presentation of the prime Sentence 3, the participant said the sentence *Sestřička podává doktorovi vodu* (ENG: A nurse is giving the doctor water), he could have repeated the order of the constituents (indirect object in DAT – direct object in ACC), but also the thematic role structure (recipient - theme). As Bernolet et al. (2012) pointed out, repetition can also be due to the information structure, where the recipient is linked to the theme, and it is this link between the emphasized object and the recipient that is repeated across sentences. However, since these experiments were not designed to distinguish between the different causes of structural priming, they do not provide an answer to the question. This is why the observed effect is referred to in this thesis by the general term structural priming rather than syntactic priming.

As noted by Ziegler and his colleagues (2019), it is possible that abstract syntactic priming is often enhanced by some other effect, otherwise it would be too weak to be noticeable. It this thesis studies it is unclear whether priming is enhanced or driven by animacy, as in almost all cases, the indirect object (recipient) in the ditransitive structures was animate and the direct object inanimate. Three other phenomena were observed in the experiments that could also enhance priming – the inverse preference effect and the boost effects of repeated morphology or words. The only structure in each experiment not subject to any of these enhancement effects is the DAT/ACC target in a *different* condition (different verb or morpheme depending on the experiment). No inverse preference effect is expected in this condition, and there is no repetition of morphological or lexical units. A look at the descriptive statistics clearly shows that in all five laboratory experiments, this is the condition with the smallest priming effect (Figures 2, 4, 8, 10 and 15).[1] This seems to supports the idea of Ziegler and his colleagues (2019) that the abstract syntactic priming must be enhanced by some other effect to be demonstrable.

[1] This is not true for the internet Experiment 5, which has its own specificities, discussed in the following section (13.2 Social factors and alignment in priming).

Figure 17

Relative amount of ACC/DAT targets after different primes in conducted experiments

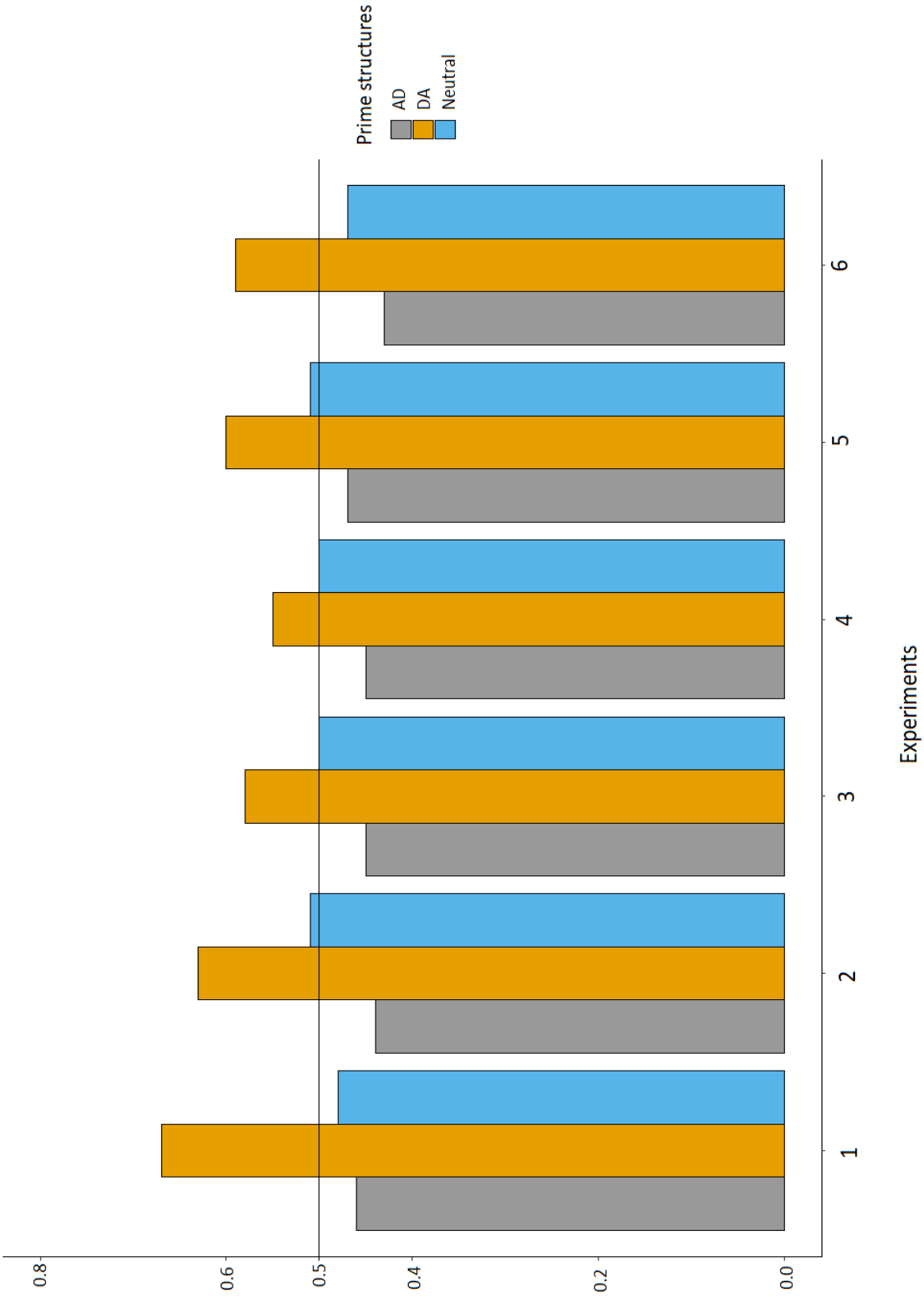


Table 35

Comparison of ditransitive priming effects between experiments

	Number of participants	Environment	Hint words	Number of produced ditransitive structures in primed condition	Number of primed ditransitive structures	Percentage of primed structures	Percentual difference between A/D and D/A targets after A/D primes	Percentual difference between D/A and A/D targets after D/A primes
Experiment 1	62	laboratory	-	304	184	61%	35%	8%
Experiment 2	63	laboratory	-	334	199	60%	26%	12%
Experiment 3	64	laboratory	yes	476	268	56%	16%	10%
Experiment 4	99	laboratory	yes	799	441	55%	10%	10%
Experiment 5	60	online	yes	396	223	56%	20%	6%
Experiment 6	61	laboratory	yes	461	268	58%	18%	16%
Average	68	-	-	462	264	57%	21%	10%

Note. Shortcuts represent ditransitive accusative/dative structure (A/D) or ditransitive dative/accusative structure (D/A).

13.2 Social factors and alignment in priming

Residual activation theory and implicit learning theory are the most influential theories explaining the mechanism of structural priming. However, they focus on the question of how priming works rather than on why structural priming occurs. On the other hand, the interactive alignment model (Pickering & Garrod, 2004) does not primarily attempt to explain how structural priming works, but offers an answer to the question of why it occurs. The theory argues that the interlocutors' language becomes aligned in dialogue which facilitates both production and comprehension. This would suggest that priming is not only driven by the simple exposure to a particular syntactic structure; it can also be modulated by top-down influences such as the presence of a second person. As has been shown in a number of studies, structural priming also occurs in monologue settings, but alignment theory predicts that the effect will be stronger in a social environment.

The aim of the present thesis was not to test the interactive alignment theory but the aroused circumstances made it possible. The first four experiments were tested in person under laboratory conditions, but after the onset of the Covid pandemic, one testing session was moved to an online environment (Experiment 5). When the restrictive Covid measurements were removed, the exact same experiment was conducted again in the laboratory (Experiment 6). This allows a comparison of priming results between less social (online) and more social (laboratory) conditions.

It is true that most of the studies that tested the alignment effect included dialogue, which was not the case in the present experiments, which were not deliberately designed to study alignment. The task was to produce speech in monologue in both online and laboratory environments, i.e., the social aspect in terms of the physical presence of the administrator was varied. However, it is possible that only the physical presence of another person is sufficient to elicit a greater priming effect (Ivanova et al., 2020).

In the laboratory experiments, participants sat in front of a computer screen and the administrator sat behind them, out of sight. However, since the administrator greeted the participants, introduced the lab, asked them to sign consents, etc., this situation was much more social than the situation in the online experiment, where the participant did not have to leave his/her room. During the online testing, participants were only able to see the administrator as a figure on the screen and only at the beginning of the experiment. They looked at the stimuli, and may not even have been aware that someone else was presenting the stimuli; they may have thought it was an automatic process.

Although the design of the two experiments (5 and 6) was otherwise identical, their results differed. Overall, slightly more target sentences were collected in the online experiment (1421) than in the laboratory experiment (1406), but almost 100 more ditransitive sentences were produced in the laboratory experiment than in the online experiment (695 and 598, respectively). Thus, the ratio of ditransitive sentences compared to the total number of produced sentences was larger in the laboratory experiment (0.49) than in the online experiment (0.42).

These descriptive data suggest that the priming effect should be larger in the laboratory experiment, as confirmed by statistical analysis. The GLMM revealed a significant effect of prime structure in the laboratory settings (p = 0.045), but only a

marginally significant effect in the online conditions (p = 0.063). All of this points to the conclusion that fewer social conditions without the physical presence of an administrator were associated with the lower priming effects. The effect of the repetition of case-ending morphemes was not significant in both experiments. However non-significant, this effect of repeated case endings seems to be supported by the descriptive data of the laboratory experiment (Figure 15), but not by the data in the online experiment (Figure 12). And perhaps the most interesting finding, the significant interaction between primate type and suffix type (the fall ending *-ovi* or *-e*), was also only visible in the laboratory experiment (Figure 16) and not in the online experiment (Figure 13).

A comparison of the experiments tentatively points to the conclusion that more social conditions produced a stronger priming effect. The question may arise why there were differences between conditions. In both conditions, the task was to produce a monologue, and the idea of alignment theory, which allows people to unify their utterances in order to achieve mutual understanding, was not fulfilled.

A possible explanation is that the physical presence of another person was sufficient to induce a greater priming effect. The same explanation was presented by Ivanova and colleagues (2020) who compared the results of their previous quasi-dialogue experiments (Ivanova et al., 2017) with monologue studies. In the quasi-dialogue settings, participants engaged in a dialogue that they believed to be sincere, but it was conducted via a computer and not with a real person. As the authors noted, there were no differences between the priming results from the quasi-dialogue and monologue (priming was found to be approximately equal in strength in both cases), leading them to hypothesize that the physical presence of the interlocutor could be the deciding factor. This is consistent with presented experiments, where neither of the two compared experimental settings involved real social dialogue and thus differed in the physical presence or absence of an administrator.

When Ivanova then compared the results from this quasi-dialogue experiment with the results from a study with a real dialogue setting (with Branigan et al., 2000), it was found that the priming effect was greater in the real dialogue setting (10-14% to 26%; Ivanova et al., 2020). These findings implicate a gradient scale of perceived sociality in the task. The higher the perceived sociality aspect of the task, the higher the priming effect. Hence, a setting without physical presence and social dialogue (online

experiments) should yield the lowest priming effect, and priming with the physical presence of a partner along with a real social dialogue (dialogue with a present interlocutor) should yield the highest priming effect. Experiments that provide only social dialogue (quasi-dialogue settings on the PC) or only the physical presence of a potential interlocutor (monologue settings with the presence of an administrator) would lie between these two borderline points.

This notion is also consistent with the only study to-date that looked specifically at the differences between priming in monologue and dialogue settings. Schoot and her colleagues (2019) compared the situation where participants were primed in dialogue settings that included a second present speaker, with a monologue situation, where they were primed by a recording. A stronger effect was found in the presence of the interlocutor, which was explained as a function of the communicative intent inserted in the conversation.

This explains why there is more priming in social situations. The more we pursue the same communicative goal, the more we have to align in order to understand each other better. When another person is nearby but not the direct addressee of the utterance, priming should be weaker. This is exactly what was found in a study by Branigan and her colleagues (2007). A participant who was present in the experimental setting but was not the direct addressee of the experimenter's speech showed smaller priming effects then the participant to whom the speech was directed.

As mentioned at the beginning of this section, interactive alignment theory explains why more priming occurs in more social situations, but not how it should work. However, according to explanations by Ivanova and colleagues (2020), attention may play a role in alignment. The authors operationalized attention as the variability in reaction time response to targets. Participants with higher variability were considered less attentive. Their data speak in favor of the hypothesis that greater attention should lead to greater alignment. This is supported by the study of Bock, Loebell and Morey (1992). In their experiment with structural priming, the participants were instructed to focus on either the form of the prime sentence or its meaning. Those who were instructed to focus on the form were primed to a greater extent than the participants instructed to focus on the meaning. The attention explanation also makes sense in terms of the results obtained by Branigan and colleagues (2007), where direct addressees of the utterance were primed more than indirect addressees, presumably because they

paid more attention to what was being said. This explanation can also be combined with residual activation theory or implicit learning theory, both of which posit the role of working memory in priming (discussed in detail in the following section). Thus, when people focus on a particular structure, that structure is dominant in their working memory, leading to a larger priming effect.

Overall, there is ample evidence to conclude that structural priming is an automatic process that increases the likelihood of reusing a perceived syntactic structure even without the presence of a dialogue partner (autopriming). However, it can be modulated by top-down social influences such as the presence or absence of a conversation partner, presumably as a function of the attention paid to the utterances.

13.3 Working memory and priming effect

The second Experiment tested the relationship between structural priming and working memory (WM). In general, memory can be divided into several levels, and, unlike episodic memory, working memory is not a representational memory. WM describes performance rather than recollection. Baddeley and Hitch's model, first described in 1974 (Baddeley & Hitch, 1974), describes WM as a temporary storage space for the manipulation of information needed for a range of complex cognitive processes, e.g. language processing. Baddeley's model of working memory distinguishes between a central executive that controls and directs WM, and its storage space – the phonological loop which stores auditory information, and the visuo-spatial sketchpad, which holds visual information (Baddeley, 2003). Later, a fourth component was added – the episodic buffer, which temporarily stores multimodal information that is bound into a single episodic representation (Baddeley, 2000).

The importance of WM for structural priming has been confirmed by several resources. Theories focusing on the implicit learning mechanism of priming often explain lexical boost as depending on WM. The lexical form of a verb can be held in WM buffers for short periods of time across sentences (e.g. Reitter et al., 2011; Heyselaar et al., 2020). Lexical and semantic information from the buffer can spread to information in long-term memory, e.g. to syntactic categories. When a verb is repeated across priming sentences, it can enhance priming. A similar explanation follows from Malhorta's (2009) dynamic mathematical model describing structural priming, where syntactic information stored in long-term memory is bound in WM with the semantic information

of the presented verb. This binding is then able to induce a lexical boost effect of structural priming. The short-term nature of WM also explains the short life of the lexical boost effect.

However, WM may not only be important for the lexical boost effect of structural priming, but also for the priming effect itself. When a verb is activated during the processing of a prime sentence, information about the structures in which the verb may occur are activated as well. This activation is held in WM and can induce the priming effect without repeating the verb. A result supporting this idea comes from Ledoux and colleagues (2007) based on their EEG experiment regarding priming in comprehension. The authors found that the syntactic property of a verb (e.g. information about its use in different syntactic constructions) can be maintained in WM. Repeating a verb across priming sentences may enhance priming. This would suggest that poorer WM should demonstrate a reduced priming effect.

A word span task and a digit span task (forward and backward) were used in Experiment 2 to measure WM. According to Baddeley's model, although the digit span task was presented verbally and the word span task visually, both stimuli should be kept by the phonological loop – since the letters that participants saw are not processed as spatial images and should be processed by the phonological loop.

The results showed no relationship between priming and working memory tasks. A correlation between the two span tasks (word and digit) was also not observed; however, forward and backward digit spans were correlated (r=0.499, *p*= 3.12e-05). The non-significant results between different span tasks are likely due to the different involvement of the central executive. The unobserved relationship between priming and WM may be due to a variety of factors. The tasks used may be too specific and, as mentioned above, they placed different demands on the central executive. It is possible that the learning mechanisms active during structural priming do not use the same WM processes that were tested in the span tasks. Syntactic repetition is probably more unconscious and takes place at a more implicit level, and therefore the central executive or phonological loop may play a very different role in it. Thus, they do not reflect the same processes that are used in structural priming.

The fact that the repetition of the verb is necessary for the WM effect to take place is another possible explanation. This would be consistent with an implicit learning mechanism. The theory emphasizes that lexical or semantic information about the verb

is stored in WM, and without verb repetition, there are no further effects of WM on priming.

However, the role played by WM in structural priming may be greater in children than in adults. Children need to hold primed syntactic structures above threshold activation in WM, and children with lower WM capacity may have difficulty holding complex syntactic structures and will not be able to repeat them. This was observed in an experiment by Foltz and colleagues (2015), where children with lower WM capacity showed fewer priming tendencies because they produced fewer RC structures than children with higher WM capacity. Furthermore, research by Kim & Yim (2016) confirmed that children's WM levels positively correlated with priming tendencies. This suggests that a certain level of WM is required to produce complex syntactic structures in children, but that WM should not play a role in adults without memory impairment.

Looking at this more broadly, there is no evidence to suggest a correlation between performance on memory span tasks and syntax repetition in Experiment 2. It is not clear evidence that WM does not play a role in structural priming, but studies with children show that WM may not play a large role in adult sentence processing.

13.4 Lexical boost effect

Previous experiments have strongly supported the lexical boost effect in priming (Pickering & Branigan, 1998; Cleland and Pickering, 2003). Although the repetition of abstract syntax occurs without the repetition of lexical units, the repetition of head constituents (mostly verbs) between prime and target sentences can enhance the priming effect (Scheepers et al., 2017). A meta-analysis of 73 studies (Mahowald et al., 2016) found that the lexical boost has an even stronger effect than structural priming, meaning that the change in the tendency to repeat the structures from no priming to priming is weaker than the change from priming without lexical boost to priming with lexical boost.

Residual activation theory proposes the lexical boost as the activation of a lemma node that encodes syntactic information (Pickering & Branigan, 1998). This idea is based on Roelof's theory (1992), who introduced a node of syntactic information in the lemma layer. This node contains information about the structures in which a particular verb may occur; hence it is sometimes called a combinatorial node. Pickering and Branigan (1998) concluded that this combinatorial node is associated with the lemma, rather than

with a specific verb form, and that it is shared between different lemmas. Since it is shared between different lemmas, different verbs that can be used in the same construction (e.g. in a ditransitive DO) can prime each other. The prime sentence activates a specific combinatorial node (e.g. ditransitive DO), and it remains activated until the production of the target sentences, increasing the probability that the same construction will be reused. If the same lemma is also reused in the target sentence, the residual activation is greater, because not only the combinatorial node but also the same lemma is activated, increasing the probability of priming even further and explaining the lexical boost effect.

The lack of evidence for lexical boost in Experiment 1 may seem surprising given the robust evidence from previous research. However, Figure 2 supports the effect of lexical boost, which suggests that the lack of significant effects may simply be due to its low statistical power. As Mahowald and colleagues (2016) noted in their meta-analysis, studies that focus on the moderating variable rather than the overall effect of priming are generally underpowered. Whether the verb was repeated between the prime and target sentence depended on the participants, and they did not repeat the verb often. The stimuli were not suggestive enough to elicit sufficient verb repetition. Having a larger sample size could have increased the amount of verb repetition and statistical power. In the following experiments, the focus was set on the morphological boost, and thus the effect of the lexical boost was not tested in other experiments.

13.5 Morphological boost

One of the main questions tested in this thesis was the existence of morphology's influence on structural priming. Only two studies have looked at such influence, specifically with regard to case-endings; one was conducted in Basque (Santesteban et al., 2015) and the other in Korean (Chung & Lee, 2017). The effect, as yet under-described in the literature, deserves more attention because, as various studies have shown, structural priming can affect many different linguistic levels (Cleland & Pickering, 2003; Pickering & Ferreira, 2008; Santesteban, Pickering & McLean, 2010). Understanding the role of morphology on structural priming is necessary to better understand the mechanism of priming, but it can also shed light on the mechanism of sentence production. The idea that morphology can boost priming is based on the *lexical*

boost effect, and has therefore been analogously referred to as the *morphological boost effect* in this thesis.

A distinction is often made between derivational morphology, which is used to form new words, and inflectional morphology. Experiments conducted in this thesis have focused only on inflectional morphology, which is used to indicate the grammatical information of a word and depends on the word's category. In English research, more attention has been paid to the inflectional morphology of verbs, which is richer than the morphology of English nouns. This is not the case in Czech. In the Czech nouns that were the focus of the experiments, the inflectional ending expresses case, number and grammatical gender. The use of inflections is restricted to conjugational classes. Two dative case endings were used in the experiments, one masculine *-ovi* and one feminine *-e*. In order for a sentence to be marked as morphologically boosted, the accusative ending *-u* should also be repeated.

Theories explaining the entire process of speech production include the individual steps of the morphological creation of words. Most theories have assumed that there are a few incremental steps in language production (e.g. Bock and Levelt, 1994; Levelt, Roelofs & Meyer, 1999). First, a non-linguistic conceptual representation of a sentence (called *message*) is created, followed by grammatical encoding, in which the correct lexical items (*lemmas*) are selected and their order is given. The next step is morphological encoding, where the case-marking morphemes are also obtained. Morphological boost theory draws from the theories that assumes that inflectional morphemes are stored separately from word stems and are put together during speech production, rather than stored together as a single word form. The results of psycholinguistic experiments confirm the distinctive character of inflectional morphemes in speech production (Pillon, 1998; Kolan et al., 2011). The last step in language production is phonological encoding, after which the sentence can be pronounced. The question is to what extent these steps develop independently of each other and to what extent they may influence each other. Some steps in the process of utterance production may run in parallel and influence each other. Some evidence comes from interactivity between the phonological and syntactic levels (e.g. Santesteban et al., 2010).

In particular, the present thesis investigated the question of whether the form of case ending can influence the selection of syntactic structure, a process that has

traditionally been seen as taking place prior to the processing of inflectional morphology (Levelt, 1993). In the research of this thesis, this influence was operationalized as a greater effect of structural priming in the condition where the case-marking morphemes were repeated between the prime and target sentences, as opposed to prime-target pairs where the repetition of the case-marking morphemes did not occur.

Experiments 2 to 6 investigated the morphological boost effect. The differences lay in their designs, but they were similar in general procedure. As explained in section 13.2 (Social factors and alignment in priming), the single online experiment (Experiment 5) had its own specificities, and the reduced priming effects observed were due to a small alignment effect. Therefore, the results of Experiment 5 will not be considered in this section and only the results of experiments 2, 3, 4 and 6 will be mentioned.

Experiment 2, which was the first to investigate the morphological boost effect, did not provide statistical evidence for the existence of this effect, but the descriptive statistics spoke in favor of it. As Mahowald and colleagues (2016) point out, studies that focus on moderating variables may be underpowered. It is possible that the study needed to collect more target sentences to register the morphological boost effect. The low power was a result of the failure to elicit the same verb responses. Thus, the following experiments included cue words under the target pictures that enhanced the production of ditransitive sentences. As predicted, this measure indeed helped to collect more primed sentences, thereby also enhancing sentences in which a morphological effect could be observed.

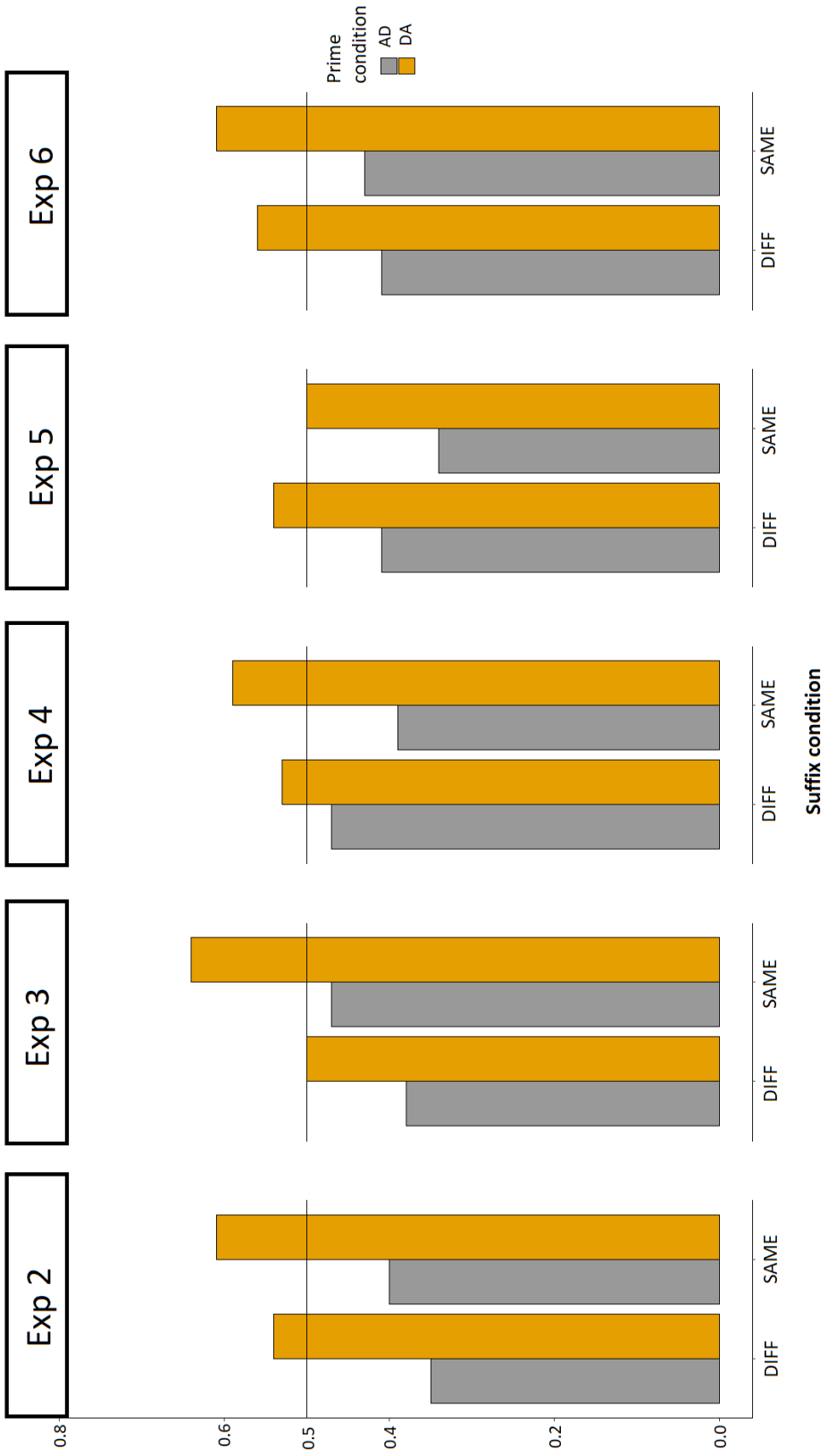
A statistical analysis of Experiment 3 yielded results in favor of a morphological boost effect ($p > 0.001$). However, the boosting of repeated morphology was only evident in the DAT/ACC constructions but not in the ACC/DAT sentences.

In Experiment 3, different target images were used for the condition where the case endings could or could not repeat. This could have led to an uneven distribution of primed sentences if some pictures were not ditransitively described as often as others. In a new Experiment 4 in which conditions were balanced, statistical analysis revealed an interaction effect between the structure and repetition of the case-marking morphemes, but it was only marginally significant ($p = 0.085$).

The experiments spoke for a morphological boost effect (Figure 18), but none of them presented reliably solid evidence. Since it was hypothesized that not all case endings had the same influence on the enhancement of the priming effect, the design

Figure 18

Relative amount of DAT/ACC targets in different or same conditions after different primes in conducted experiments



was changed slightly. Only the two previously used case endings in the dative (*-ovi* and *-e*) were retained in the test stimuli, and the possibility of their different functioning was tested. As mentioned earlier, no evidence of a morphological boost or the differential functioning of the different endings was found in online Experiment 5. Since the overall priming effect in this experiment had a different tendency than all of the other experiments, it was concluded that online testing was not appropriate for studying priming, and a laboratory Experiment 6 with the same design was conducted.

The overall effect of morphology on structural priming was not observed in Experiment 6. Both conditions (same and different suffix) showed a tendency to priming, but there was no statistical difference between them. A model that included suffix type as a factor showed a significant interaction between structure type and suffix type. A priming effect for the DAT/ACC structure was observed for both suffixes *-ovi* and also *-e*, but was greater in the suffix *-ovi* condition. The priming effect for the ACC/DAT structure was present only for the case ending *-ovi* and not for the case ending *-e* (Figure 16). This points to the conclusion that the case ending *-ovi* indeed has a greater morphological boost effect than the ending *-e,* and suggests that different case-marking morphemes may have different boost effects on structural priming.

Pickering and Branigan (1998) showed that inflectional morphology does not play a role in structural priming in English; however, they focused on the inflectional morphology of verbs. Since the case ending encodes the case in Czech nouns, it is needed to decode the recipient (indirect object) and the theme (direct object) in ditransitive sentences. In comparison, the inflectional morphology of verbs mainly encodes a grammatical function and can therefore be processed differently than the case endings of nouns, e.g. at a different processing stage or with less intensity.

The different results obtained in English may also be due to the simple fact that different languages have different processing requirements. In English, inflectional morphology is richer for verbs, but this is not the case for Czech with its rich inflectional morphology for nouns. There is no canonical dative/accusative ordering in Czech; although the DAT/ACC structure is more frequent, the ACC/DAT structure is also common. Information about what constitutes the direct and indirect object cannot be directly inferred from any other syntactic information, the listener needs a clue in the form of a case ending to understand the message. Therefore, the case ending morphology encodes crucial information about the meaning of a sentence and can be

highlighted in Czech language processing. It is true that animacy can also serve as a clue in Czech. Since the direct object is inanimate in most occurrences and the indirect object is mostly animate, animacy can often help to correctly decode the message of the utterance in (e.g. Pán dáva ženě vodu. ENG.: The man gives the woman some water). However, the animacy of direct and indirect objects may vary and therefore cannot serve as an absolutely reliable clue to decoding the direct and indirect objects. The fact that different morphemes in Experiment 6 showed a different morphological boost effect also points to the conclusion that the case-marking morphemes play a role in a syntactic processing.

Based on this comparison, it cannot be concluded whether the difference arises because different language types process inflectional morphology to different extents, or whether the difference lies in the different processing of the inflectional morphology of different word classes (nouns vs verbs).

The study in Basque (Santesteban et al., 2015) found no boost effect of case endings of nouns and concluded that the marking for inflection occurs only after structural selection (Bock & Levelt, 1994). However, the authors did mention that case markings can play a role in structural priming, in contexts where the morphological element is important for identifying the sentence constituents. This is, as mentioned above, the case of Czech. The results of this thesis do not stand in opposition to Basque results; Czech results do not mean that case marking occurs before structural selection, although the results did confirm that case ending morphology has an effect on syntactic structure. However, a more likely explanation is that inflectional morphology may affect the order of the constituent structure after structural selection, or that the processing of the constituent order and word morphology occurs in parallel.

In the Basque study, 4 experiments were conducted. Only the Basque Experiment 4 focused on the effect of case endings in priming situation where the prime and target were structurally identical (as in this thesis experiments). However, the conditions in Basque Experiment 4 were again different from those in this thesis. Although the structures that primed each other had the same constituent structure (NP – PP – V), the primes used non-psychological verbs and the targets used psychological verbs. The effect under investigation was that of an absolutive case that is marked by a null morpheme, but the present thesis focused on the effects where morphemes were overtly marked. This may have led to different results in the Czech and Basque experiments. The

reason for the discrepancy between experiments may also lie in the differences between the grammars of the languages and their different processing (Hwang & Kaiser, 2014; Norcliffe et al., 2015; Egurtzegi et al., 2022).

The second study that investigated the effect of the case-ending morphemes of nouns was conducted in Korean (Chung & Lee, 2017). The Korean study examined whether the accusative suffix would be repeated or dropped, while the Czech study examined whether the word order will be repeated more often when nouns identical endings are chosen. The Korean study found an enhancement effect of the case-ending morphemes and supports the findings of this thesis.

In summary, this thesis has shown an interplay between the processing of inflectional case-marking morphemes and the choice of syntactic structure. Although the results can add missing information to the discussion of the interactivity of the morphological and syntactic levels in language processing, they have several limitations. The constraints of this interactivity between linguistic levels are not clear; it can be limited by the language type, class of inflected word, or both. In Czech, the processing of noun morphology may be more important. This is because in Czech it provides information of the noun's constituent role that cannot be obtained from other grammatical indicators, such as word order. It is also not clear whether the boost effect of noun endings is transferable to other word types in Czech, i.e. whether the inflectional morphology of Czech verbs would have a boost effect. Future research in these areas is needed to provide these answers.

Another finding that deserves future investigation is the boosting effect of different types of case endings. The case ending morpheme *-ovi* was found to cause a greater priming effect than the case marking morpheme *-e*. Words with the case ending *-ovi* have an additional syllable compared to the nominative form, while forms marked with *-e* have the same number of syllables as their corresponding nominatives. The ending *-ovi* may be processed differently because it is more prominent as a syllable and is more salient for attention. When attention is focused on the *-ovi* ending for longer, it may lead to its greater activation in the following sentence.

14. Conclusion

The main aim of this thesis was to investigate the effect of structural priming in Czech. The structural priming effect was established for ditransitive structures with an alternation of the DAT/ACC and ACC/DAT word orders. An inverse preference effect was also confirmed, as less frequent ACC/DAT structures were primed to a greater extent. No priming effect was observed for SVO/OVS structures, probably because they are strongly marked for the information structure.

Several factors that may influence the effect of priming were also tested. The most important was the finding that the repetition of the case-marking morphemes of nouns can enhance the effect of structural priming. This suggests that syntactic processing is not completely independent of morphological processing and they are processed at least partially in parallel. However, it appears that not all case-marking morphemes had the same boost effect; the more prominent endings (*-ovi*) enhanced priming, but not the less prominent endings (*-e*).

The effect of lexical boost was not confirmed in this thesis, but robust evidence from other studies suggest that this was due to the small number of collected sentences. The effect of working memory was also not observed. This may be because working memory can only affect structural priming in younger children, while in healthy adults it has developed to the point where it no longer plays a role. Interestingly, the priming effects in the online experiment were not as strong as those in the laboratory experiments. This is in line with the interactive alignment theory, which argues that priming is greater in social situations. The experiments showed that dialogue does not need to take place and that the mere physical presence of a potential interlocutor may be sufficient to boost priming.

Overall, this thesis replicated robust findings from other languages and demonstrated that structural priming occurs in Czech. The greatest contribution of the work is the finding that the morphological level can influence syntactic processing, suggesting that these two linguistic levels interact with each other in language processing.

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