Language processing in a conversation context

Lotte Schoot

Cover design by Jeroen Bekkers & Lotte Schoot

Printed and bound by Ipskamp Drukkers b.v.

The research reported in this thesis was carried out at the Max Planck Institute for Psycholinguistics, in collaboration with the Donders Institute for Brain, Cognition and Behaviour, Centre for Cognitive Neuroimaging, Radboud University Nijmegen.

Language processing in a conversation context

Proefschrift

ter verkrijging van de graad van doctor

aan de Radboud Universiteit Nijmegen

op gezag van de rector magnificus prof. dr. J.H.J.M. van Krieken,

volgens besluit van het college van decanen

in het openbaar te verdedigen op maandag 20 februari 2017

om 10.30 uur precies

door

Lotte Schoot

geboren op 11 mei 1990

te ’s-Hertogenbosch

Promotor: Prof. dr. P. Hagoort

Copromotor: dr. K.R. Segaert (University of Birmingham, Verenigd Koninkrijk)

Manuscriptcommissie:

Prof. dr. A.S. Meyer

Prof. dr. E.J. Krahmer (Tilburg University)

Dr. R.M. Willems

Table of Contents

Chapter 1 7
Chapter 2A 19
Chapter 2B 59
Chapter 3 77
Chapter 4 109
Chapter 5 149
Chapter 6 167
Chapter 7 194
References 209
Samenvatting 225
Acknowledgements 233
Curriculum Vitae 237
Publications 237
MPI Series in Psycholinguistics 239

CHAPTER 1

General Introduction

We use language every day: when we read the paper, write emails, listen to the radio, or engage in conversation with others. Out of all these situations, having a conversation is probably the most natural form of language use (Pickering & Garrod, 2004). It is therefore surprising that many studies into the cognitive and neural mechanisms that enable us to produce or comprehend language investigate these processes in isolation. That is, in these studies, participants are required to speak without having a person to talk to, or listen without knowing who the speaker is or having to respond to them. Although such paradigms are a valid way to study many aspects of language comprehension and production, a full model of language processing should also account for language use in natural contexts, such as conversation. In this dissertation, I focus on language comprehension and production in a conversation context. I zoom in on three core features of conversation: 1) interlocutors in a conversation take turns between speaking and listening; 2) conversation is a social activity; 3) in conversation, language is used to communicate.

The first important aspect of conversation is that interlocutors talk to each other, taking turns between speaking and listening. Efficient and fast turn-taking requires tight coordination between a person's language comprehension and production processes. Previous work has already shown that language production and comprehension processes automatically influence each other. We can also rephrase this; in conversation, two speakers influence each other. What you hear your conversation partner say automatically influences what you say next, and vice versa. When looking at comprehension-production interactions as between-speaker effects, we have to take into account the two other core aspects of conversation that it is a social activity, and that language is used for communication. Indeed, the speakers in a conversation engage in this interaction with individual, social goals (e.g. to make a positive impression on their partner) and/or joint, communicative goals. Interestingly, it has been hypothesized that conversational goals interact with how much speakers are influenced by their partner. In this thesis, I focus on syntactic priming effects as an example of how interlocutors are automatically influenced by their conversation partner (see section 1.1). Moreover, I investigate how speakers' social and communicative goals may influence the magnitude of these syntactic priming effects (see section 1.2).

I do not only address the possible influences of having a communicative (and/or social) goal on syntactic priming magnitude. Indeed, studying syntactic priming effects in brain and behaviour provides a window onto the mechanisms which underlie successful communicative behaviour in conversation. But what about the ultimate goal of communication itself: mutual understanding of the situation under discussion, or in other words, situation model alignment? Little is known about the neural mechanisms associated with higher order alignment. In this dissertation, I explore the possibilities of taking a novel, two-brain approach to study mutual understanding (see section 1.3).

In the remainder of this introduction, I briefly introduce the empirical chapters of this thesis (chapters 2 - 6), together with some methodological and theoretical concepts that are crucial for interpreting the design and results of these chapters.

1.1. Syntactic priming effects in brain and behaviour

The syntactic priming effect is an extensively investigated phenomenon in psycholinguistics, and best known as the speaker's tendency to repeat sentence structures (syntax) they have recently processed. This effect has also been called syntactic alignment or structural persistence. Imagine, for example, a picture of a man kissing a woman. Speakers would generally not tend to describe this picture with a sentence like '*the woman is kissed by the man*' (a sentence in the non-preferred passive voice). However, they are more likely to do so if they had just heard or produced another sentence in the passive voice, such as '*the boy is hugged by the girl*'. Hence, speakers are primed by the syntactic structure of the first sentence, which leads to an increased chance of repeating that structure in the subsequent utterance. After the first experimental demonstration of syntactic priming effects in syntactic choices (Bock, 1986), an extensive body of studies has replicated this effect for various syntactic structures and in different languages (for a recent overview see Mahowald, James, Futrell, & Gibson, 2016).

Syntactic priming effects are not only reflected in the speaker's syntactic choices: speakers are also faster to produce sentences with the same structure as the preceding sentence, relative to when they produce that same structure in a non-repetition condition (priming effects in speech onset latencies: Corley & Scheepers, 2002; Segaert, Menenti, Weber, & Hagoort, 2011; Segaert, Weber, Cladder-Micus, & Hagoort, 2014; Segaert, Wheeldon, & Hagoort, 2016; Smith & Wheeldon, 2000; Wheeldon & Smith, 2003). Similarly, less brain activity is required to produce a sentence with repeated structure with respect to a sentence with a novel structure (the repetition suppression effect in fMRI BOLD response (Menenti, Gierhan, Segaert, & Hagoort, 2011; Segaert, Menenti, Weber, Petersson, & Hagoort, 2012)).

Each of these manifestations of the effect of syntactic priming, whether on the behavioural or brain level, indicates that there is a facilitating effect of priming on syntactic processing. These facilitation effects have been explained by accounts focusing on implicit learning mechanisms (Chang, Dell, & Bock, 2006; Chang, Dell, Bock, & Griffin, 2000; Jaeger & Snider, 2013), accounts based on residual activation (Pickering & Branigan, 1998) or a combination of both (Reitter, Keller, & Moore, 2011).

1.2. Syntactic priming in conversation

One influential theory (the Interactive Alignment Model; Garrod & Pickering, 2009; Pickering & Garrod, 2004) is that priming is a mechanism that ensures interlocutor alignment of their linguistic representations at various levels, e.g. phonetics (sound), semantics (meaning), and syntax (structure). Crucially, these authors argue that alignment at lower linguistic levels percolates up and therefore facilitates alignment at higher levels of representation. When interlocutors are aligned at the highest representational level, i.e. the level of the situation model, they have achieved mutual understanding of the situation under discussion, which is a communicative success. In this framework, priming is therefore a mechanism to align representations and thus ultimately to facilitate communication (see also

(Branigan, Pickering, Pearson, & McLean, 2010; Jaeger & Snider, 2013). In addition, it has been proposed that syntactic priming effects are used to mediate interpersonal distance between speakers (Balcetis & Dale, 2005; Coyle & Kaschak, 2012; Giles & Powesland, 1975; Weatherholtz, Campbell-Kibler, & Jaeger, 2014).

Crucially, these theories suggest that the magnitude of syntactic priming effects is - at least in part - driven by social and communicative factors that play a role in conversation. I test the communicative hypothesis in chapters 2 and 3 by comparing syntactic priming magnitude of participants who are primed by a recording with the magnitude of participants who interact with a real, human conversation partner. Only in the latter condition, participants have the goal of aligning their situation models with their partner. In **chapter 2A**, I focus on how having an (unconscious) goal to align situation models influences syntactic priming effects in the brain (repetition suppression effects in production and comprehension) and in speech onset latencies. In the latter measure, I also explored whether interlocutors are influenced by the syntactic priming magnitude of their partner. Since this is a novel approach, I report the results of a replication study in **chapter 2B**. I approach the same question with a free choice paradigm in **chapter 3**, to test the effect of having a real partner and a communicative goal on syntactic priming effects in the speaker's syntactic choices (syntactic alignment). An orthogonal manipulation allowed us to test the hypothesis that free choice syntactic priming effects are influenced by the priming magnitude of their partner. In **chapter 4,** I test whether a speaker's (desired) social relationship with their partner influences the strength of syntactic alignment by manipulating whether they know that they will be evaluated by their partner after the experiment. In other words, I manipulate the primed participant's desire to impress their partner. In addition, I test whether syntactic priming of one speaker actually affects how this speaker is perceived by their conversation partner.

Box I. Experimental paradigms to study syntactic priming

In chapters 2, 3 and 4, I measure syntactic priming effects in participant's syntactic choices, in speech onset latencies and in neural activation, as measured by repetition suppression effects in the fMRI BOLD response (box II). In all of these paradigms, participants are presented with prime pictures, followed by target pictures. Syntactic priming effects are measured on the targets. All target pictures depict two actors: one is the agent, performing an action; the other actor is the patient, undergoing the action (e.g. a man chasing a woman or a girl drawing a boy). These actions can be described by transitive verbs and the whole event may be described by a sentence in the active voice (the man is chasing the woman) or in the passive voice (the woman is being chased by the man).

Two paradigms were used to measure syntactic priming effects. To measure priming effects in speakers' syntactic choices, I make use of a *free choice paradigm*: target pictures are presented in grayscale and participants are free to describe the picture with whichever sentence structure they like (active or passive voice). For free choice paradigms, there is a syntactic priming effect when participants produce more descriptions in the (non-preferred) passive voice after hearing a passive prime sentence than after a baseline prime (e.g. the boy runs, intransitive action). This effect is visualized in Figure 1A.

To measure syntactic priming effects in speech onset latencies or in the BOLD response, I make use of a different paradigm in which participants are not free to choose which syntactic structure they use to describe target pictures: a *forced choice paradigm* (the stop-light paradigm; Menenti et al., 2011). Pictures are color-coded and participants have to describe the green actor before the red actor. This way, I control the syntactic structure they use: when the agent is green, they have to produce an active sentence, and when the patient is green, they have to produce a passive sentence. This control is necessary because speakers' natural preference for active sentences would lead to an unequal number of primed and non-primed active and passive sentences, not allowing for statistical comparisons between conditions in the noisy fMRI signal. There is a syntactic priming effect in speech onset latency when speakers are faster to produce a target structure when preceded by a prime with the same structure than when the target was preceded by a prime sentence with a different structure (Figure 1B). Both syntactic priming effects in speech onsets latencies and syntactic choices are behavioural outcomes of priming effects at the neural level. There is less neural activation needed for sentences with repeated relative to novel structure (Figure 1C).

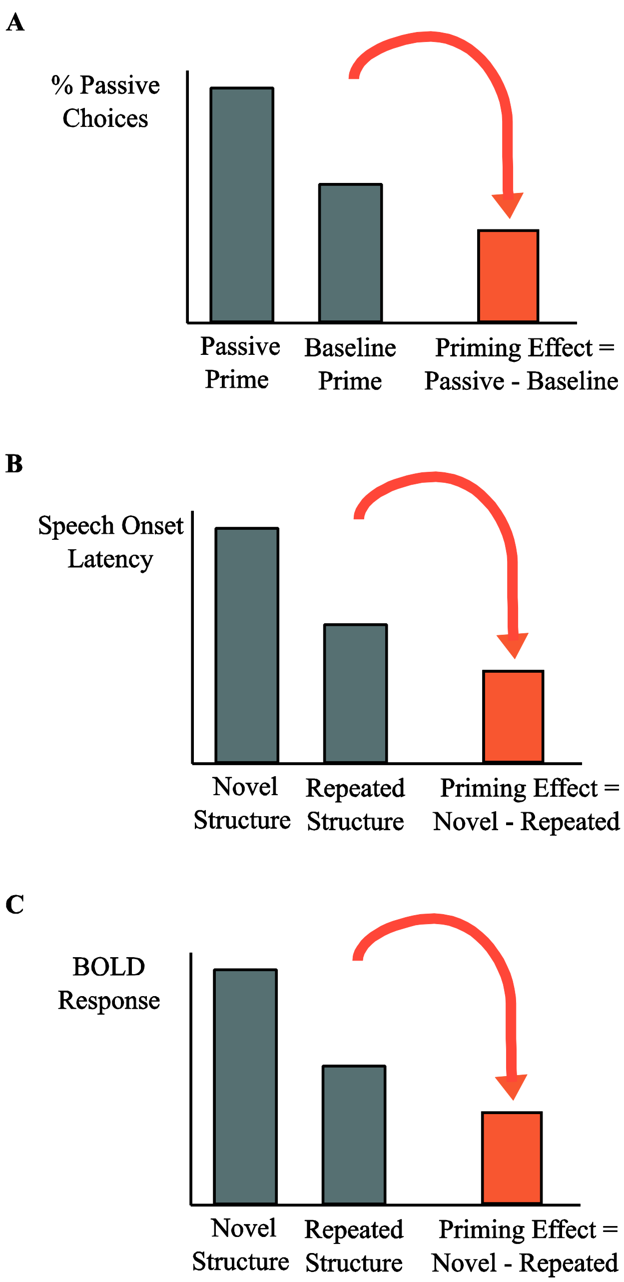

Figure 1. (A) If there is a syntactic priming effect in choices, speakers produce more passives after a passive prime than after a baseline prime. **(B)** If there is a syntactic priming effect in speech onset latencies, speakers are faster to produce sentences with repeated structure than they are to produce sentences with novel structure. **(C)** Syntactic priming effects in BOLD response indicate that there is less neural activation needed for sentences with repeated relative to novel structure.

1.3. The goal of conversation: alignment of situation models

In chapters 5 and 6, I return to the idea of situation model alignment being the ultimate goal of conversation, or in fact communication in general (Pickering & Garrod, 2004). Only when interlocutors have come to understand the relevant aspects of what they are talking about in the same way, i.e. they have constructed a similar mental model of the situation under discussion (Zwaan & Radvansky, 1998), can communication be considered to have been successful (Menenti, Garrod, & Pickering, 2012).

Although conversation and communication are ubiquitous in our everyday lives, the neural mechanisms that contribute to mutual understanding are still poorly understood. In chapters 5 and 6, I explore a novel way of measuring situation model alignment between interlocutors by looking at the overlap in the two interlocutors' neural response patterns, making use of a two-brain approach to verbal communication. Indeed, successful communication can only exist between interlocutors: it is therefore argued that in order to get a full understanding of the neural mechanisms that enable successful communication, the field should move away from studying one individual's neural responses and focus on the dynamic interplay between the neural responses of two participants in an interaction (e.g. Hari, Henriksson, Malinen, & Parkkonen, 2015; Hasson, Ghazanfar, Galantucci, Garrod, & Keysers, 2012).

In **chapter 5**, I present a theoretical overview in which I explore whether the two-brain approach can contribute to the study of verbal communication in a way that one-brain studies cannot. Based a previously proposed theoretical framework (Friston & Frith, 2015a; Friston & Frith, 2015b), I argue that between-subject correlations in brain activity of speaker and listener may reflect alignment of linguistic and extra-linguistic representations. This leads to the intuitively appealing idea that between-subject correlations may reflect situation model alignment or mutual understanding of the situation under discussion. This idea is further tested in the last empirical chapter; **chapter 6**. I measured brain activation (fMRI BOLD response, box II) for the speaker and listener in a communicative pair, and investigate whether the degree to which the speaker and listener's neural activation patterns are correlated is predicted by the degree to which they have aligned their situation models.

Box II. fMRI and the BOLD response

In chapters 2, 5 & 6, the results of functional magnetic resonance imaging (fMRI) paradigms are discussed. fMRI is one technique to measure neural activity in the brain. This technique makes use of the different magnetic properties in oxygen-rich and oxygen-poor blood, the ratio of which is reflected in the BOLD (Blood Oxygen Level Dependent) signal. When neurons are active, they consume oxygen, leading to a change in the ratio between oxygen-rich and oxygen-poor blood, which, in turn, affects the BOLD signal. The BOLD signal is therefore thought to be a good reflection of neural activation in the brain, with high spatial resolution (measured per voxel, a three-dimensional 'pixel'). However, the temporal resolution of fMRI is low: the BOLD signal is sluggish and only peaks around 6 seconds after neurons were actually active.

CHAPTER 2A

The influence of communicative context on syntactic priming in brain and behaviour

Adapted from: Schoot, L., Menenti, L., Hagoort, P., & Segaert, K. (2014). A little more conversation–the influence of communicative context on syntactic priming in brain and behavior. *Frontiers in psychology*, *5*.

Abstract

We report on an fMRI syntactic priming experiment in which we measure brain activity for participants who communicate with another participant outside the scanner. We investigated whether syntactic processing during overt language production and comprehension is influenced by having a (shared) goal to communicate. Although theory suggests this is true, the nature of this influence remains unclear. Two hypotheses are tested: i. syntactic priming effects (fMRI and RT) are stronger for participants in the communicative context than for participants doing the same experiment in a non-communicative context, and ii. syntactic priming magnitude (RT) is correlated with the syntactic priming magnitude of the speaker's communicative partner. Results showed that across conditions, participants were faster to produce sentences with repeated syntax, relative to novel syntax. This behavioural result converged with the fMRI data: we found repetition suppression effects in the left insula extending into left inferior frontal gyrus (BA 47/45), left middle temporal gyrus (BA 21), left inferior parietal cortex (BA 40), left precentral gyrus (BA 6), bilateral precuneus (BA 7), bilateral supplementary motor cortex (BA 32/8) and right insula (BA 47). We did not find support for the first hypothesis: having a communicative intention does not increase the magnitude of syntactic priming effects (either in the brain or in behaviour) per se. We did find support for the second hypothesis: if speaker A is strongly/weakly primed by speaker B, then speaker B is primed by speaker A to a similar extent. We conclude that syntactic processing is influenced by being in a communicative context, and that the nature of this influence is bi-directional: speakers are influenced by each other.

2.1. Introduction

Although in everyday life, the purpose of using language is to communicate, participants in most psycholinguistic experiments use language devoid of any communicative goal: they speak without addressing someone or listen without being addressed directly. The implicit assumption here is that core language processing in the brain is not influenced by whether or not the speaker or listener is in a communicative context and that therefore, non-communicative language experiments can be used to infer what happens in real-life communicative situations. Although we do not wish to imply that this method is incorrect, it has been repeatedly shown that linguistic and extra-linguistic contextual factors can have a significant influence on core language processes (e.g. Hanulíková et al., 2012; Nieuwland & Van Berkum, 2006; Van Berkum et al., 2008). In the current study, we investigate whether being in a communicative context influences core language processing in the brain. Previous studies have reported that certain social factors, which are inherent to any communicative context, can influence core language processing. For instance, (inferred) speaker characteristics can influence semantic (Van Berkum et al., 2008) and morpho-syntactic processing (Hanulíková et al. 2012) during language comprehension. Here, we focus on another important aspect of being in a communicative context: having (and perhaps sharing) the intention to communicate. Having a communicative intention engages certain brain regions which do not show activation for speakers without such an intention (see Willems & Varley, 2010). What has not been investigated yet is whether having a (shared) goal to communicate influences how core linguistic information, such as syntax, is processed in the brain. This is the focus of the present study.

We make use of the phenomenon that speakers tend to repeat syntax across sentences, which is known as syntactic priming or structural persistence (Bock, 1986). A large body of research on this topic shows that syntactic priming is not only reflected in production preferences but also in response latencies and brain activation; compared to production of a sentence that is syntactically different from its preceding sentence, speakers start speaking faster (Smith & Wheeldon, 2000) and show less brain activation (Menenti et al., 2012) when they produce a sentence with repeated syntax. Furthermore, syntactic priming effects are not only found for production, but also for comprehension: listeners expect subsequent sentences to have the same syntax (Branigan et al., 2005; Thothathiri & Snedeker, 2008), and again, less brain activation is needed to comprehend repeated sentence structures than novel sentence structures (Menenti et al., 2011; Noppeney & Price, 2004; Weber & Indefrey, 2009). Of importance for the present study is that syntactic priming effects do not only occur within-modalities (production-to-production or comprehension-to-comprehension priming) but also between modalities - and thus, crucially, between speakers (comprehension to production or production to comprehension priming). Speakers not only repeat their own syntax, but also the syntax of others (Bock et al., 2007; Branigan et al., 2000; Potter & Lombardi, 1998) and they expect others to repeat their own syntactic structures back to them (Ferreira et al., 2012). Similarly, suppressed brain activation is found both within and between speakers, for production and comprehension in the same brain regions (Segaert et al., 2012).

Despite the vast number of studies that report different types of syntactic priming effects, there is no definite answer as to why speakers tend to repeat syntactic structures. Well established accounts of syntactic priming propose residual activation (Pickering & Branigan, 1998) or implicit learning (Chang et al., 2000; Chang et al., 2006) as an underlying mechanism, or a hybrid account with elements of both mechanisms (Reitter et al., 2011). Another proposal is that priming has an important communicative function (Pickering & Garrod, 2004; Jaeger & Snider, 2013). If the latter proposal is true, syntactic priming effects should be influenced by being in a communicative context. To date, however, the nature of this influence remains unclear. In this study, we test two specific hypotheses. Both follow from the hypothesis that communicative context has a top-down influence on syntactic priming effects, but they differ with respect to the nature of this influence. However, we do not claim that these hypotheses are necessarily mutually exclusive.

The first hypothesis is that having a (shared) goal to communicate increases the magnitude of an individual's syntactic priming effects (Garrod & Pickering, 2009). This hypothesis fits well within the *mutual expectation adaptation* model by Jaeger and Snider (2013). This model centres on the idea that listeners (unconsciously) make predictions about upcoming input in order to process language input efficiently. If the listener's prediction is wrong, however, more processing is needed to overcome this prediction error (cf. Friston, 2005), which will in turn slow down and/or make comprehension more effortful. Jaeger and Snider propose that speakers can contribute to the minimization of the listener's prediction error (and thus their comprehension ease) by aligning what they say to (their beliefs about) what the listener expects them to say. Because a listener generally expects syntactic repetition, the listener's comprehension is facilitated if speakers indeed repeat syntax. In conversation, therefore, both the speaker and the listener are trying to make information transfer as fast and efficient as possible, by contributing to what Jaeger and Snider refer to as *mutual expectation adaptation*. Syntactic priming effects are a reflection of this process.

If speakers repeat sentence structures because they (unconsciously) believe this facilitates comprehension for the listener, they should be less likely to do so when it is less urgent to make the listener understand what they are trying to communicate. Similarly, listeners may expect more repetition from the speaker if they know that the speaker wants to convey a message to them (Jaeger & Snider, 2013). There are some studies that seem to provide evidence in favour of this hypothesis, reporting stronger syntactic priming effects as the need for (efficient) communication increases (Branigan et al., 2000, Reitter et al., 2006). However, there are also studies that report no difference (Bock et al., 2007), or seem to point in the opposite direction (Ferreira et al., 2012). None of these studies, however, can provide definite evidence in favour of or against the hypothesis. Either the experimenters varied not only communicative intention, but also other aspects of the task (Branigan et al., 2000; Reitter et al., 2006; Bock et al., 2007), or the task is the same, but communicative intention is manipulated for either the prime or the target but not for both (Branigan et al., 2007; Ferreira et al., 2012). None of these studies have compared syntactic priming effects within the exact same task, while only varying the context (communicative or non-communicative) in which participants perform this task, during both target and prime. Furthermore, although the influence of having a communicative intention may be different during production and comprehension, none of these studies have investigated and compared syntactic priming effects in production as well as comprehension. Here, we do include all these aspects in one study in order to test whether syntactic priming effects in production and/or comprehension increase when interlocutors have a (shared) goal to communicate with each other.

The second hypothesis that we will test here takes into account the fact that syntactic priming magnitude may not (only) be influenced by the speaker's beliefs about the interlocutor's expectations, but also by the interlocutor's actual linguistic behaviour: the magnitude of the interlocutor's syntactic priming effects. Previous studies have repeatedly shown that speakers tend to mimic certain aspects of their interlocutor's linguistic behaviour, such as accent (Giles & Powesland, 1975), speech rate (Webb, 1969) and speech rhythm (Cappella & Planalp, 1981). Pickering and Garrod (Pickering & Garrod, 2004) have proposed that this kind of automatic mimicking will lead interlocutors to align their representations at different levels of linguistic processing (in the examples above, alignment will occur at the phonetic level). Alignment at lower levels can then lead to increased alignment at higher levels of processing, with the ultimate goal of achieving alignment at the level of the situation model: speakers' representations of the situation under discussion. Alignment at this level, Pickering and Garrod argue, is a prerequisite for successful communication. On their own, syntactic priming effects already reflect a speaker’s (unconscious) efforts to align their syntactic representations with the interlocutor by mimicking his or her syntactic structures. Here, however, we hypothesize that how strong these syntactic priming effects are is yet another aspect of linguistic behaviour that is unconsciously and automatically mimicked by interlocutors. If we take the predictions of Jaeger and Snider’s *mutual expectation adaptation* model into account, repetition will only facilitate communication if it is expected by the listener. But how does the speaker know how much repetition the listener expects? One option may be to adapt the amount of repetition to the amount of repetition used by the interlocutor. If this is true, this implies that the magnitude of syntactic priming effects should not be studied from an individualistic perspective. Rather, we should take into account the fact that speakers influence each other. This prediction will be tested in the present study: in addition to comparing priming effects of individual participants in a communicative and a non-communicative context, we correlate the strength of priming effects of two participants within one communicative pair.

We test the two hypotheses outlined above using the results of a syntactic priming study. Participants are assigned to a communicative or to a non-communicative condition. The experimental task is identical in both conditions: participants either have to describe photographs of two persons performing a transitive action (e.g. feeding or serving), or listen to descriptions of these photographs and decide whether the photograph matches the description. The difference between the communicative and non-communicative condition is that only in the communicative context, participants work together with another (naive) participant, whereas in the non-communicative context, participants perform the experiment alone, speaking without addressing anyone and listening to pre-recorded sentences. In the communicative condition, the two participants thus describe the photographs to each other: they share the goal to communicate with each other. This goal is absent the non-communicative condition. Therefore, a comparison between participants in these two conditions provides us with a way to test our first hypothesis: syntactic priming effects are stronger when participants have a (shared) goal to communicate. Because we furthermore aim to compare the influence of communicative context on syntactic priming in production and comprehension, we need to measure syntactic priming effects in the same way for both modalities. This is possible using fMRI: brain activation related to syntactic processing can be measured in the same regions for production and comprehension. We make use of the fMRI adaptation effect, where the blood oxygen level dependent (BOLD) response in certain regions of the brain is reduced when a sentence structure is repeated (Ganel et al., 2006; Grill-Spector & Malach, 2001; Segaert et al., 2013). Priming effects can thus be measured by looking at the decrease of the BOLD-response for sentences in which syntax is repeated, relative to non-repeated. Since these fMRI adaptation effects can be measured in the same brain regions for syntactic priming in production and comprehension (Menenti et al., 2011; Segaert et al., 2012), they provide us with a good measure to compare the strength of syntactic priming effects in different processing modalities, as well as between contexts (communicative vs. non-communicative).

We only obtained fMRI measurements of one of the participants in the communicative context. Therefore, we cannot use fMRI measurements to test our second hypothesis that the priming effects of one participant are influenced by the priming effects of his or her behavioural partner. However, we did obtain behavioural measurements (speech onset latencies) for both participants in a communicative pair. As said above, speech onset latencies show syntactic priming effects if there are faster speech onsets for target sentences with repeated sentence structure relative to sentences with novel sentence structure. The magnitude of priming effects of each individual participant in the communicative context will be correlated with the magnitude of the priming effects of their conversation partner. This analysis will test whether speakers are indeed influenced by the priming effects of their interlocutor.

Thus, in this study, we investigate whether being in a communicative context, i.e. having - or sharing - the intention to communicate, influences core language processing. Specifically, we wish to empirically test the theoretical proposal that syntactic priming effects are subject to the top-down influence of being in a communicative context. We derived two (not mutually exclusive) hypotheses from this proposal, which we test in the present study. The first hypothesis is that the presence of a communicative context will increase the magnitude of the syntactic priming effects. To test this prediction, we compare syntactic priming effects in overt production (both behavioural - speech onset latencies - and in the brain - fMRI adaptation effects) and comprehension (in the brain) of participants in a communicative versus a non-communicative context. The second hypothesis is that priming effects of one person are influenced by the priming effects of the other person: if person A accommodates to person B, then person B will accommodate to person A to a similar extent. To test the latter prediction, we correlate (behavioural) priming effects measured during language production of two participants in a communicative pair.

2.2. Methods

For the present report, we collected data from participants who perform a syntactic priming experiment in a communicative context: one participant is in the MRI scanner and the other one performs the experiment in a behavioural experiment room (see Figure 2.1). This dataset could be used to test the (second) hypothesis that priming effects of one person are influenced by the priming effects of their communicative partner. To test the (first) hypothesis that syntactic priming effects are stronger in a communicative context, we compare participants in a communicative context with participants in a non-communicative context. The data on syntactic processing in a non-communicative context were collected before and have already been reported on in Segaert et al. (2012). To be able to compare the two contexts, we kept all aspects of the testing procedure and fMRI data acquisition parameters maximally similar. As a consequence, the experiment in the communicative context was performed as previously described in Segaert et al. (2012) with identical materials and methods. The one crucial difference between the communicative and non-communicative context was that in the non-communicative context, participants performed the experiment alone, whereas in the communicative context, participants worked together with another participant.

2.2.1. Participants

For twenty-four participants in the non-communicative condition (12 male, mean age 22 years, SD = 4.8) fMRI (and simultaneously also behavioural) measurements were obtained. In the communicative condition, we paired two participants (one in the MRI room and one only behavioural participant): there were 24 participant pairs (48 participants). The 24 MRI participants in the communicative condition (11 male, mean age 21 years, SD= 2.35) had a similar distribution of sex and age as the 24 participants in the non-communicative condition. The 24 behavioural-only participants in the communicative condition (5 male, mean age 20.5 years, SD= 2.37) were not gender matched with either group of MRI participants. Participants pairs in the communicative context condition (1 male-male pair, 10 male-female pairs, 4 female-male pairs and 9 female-female pairs) did not know the partner they would cooperate with during the experiment. However, they met each other before entering the experiment room and they interacted during the instructions and sound set-up and during the break. All participants were right-handed native Dutch speakers without neurological or language impairments and with normal or corrected to normal vision. Participants had attended or were attending university education in the Netherlands and gave written informed consent prior to the experiment. They were always compensated for their participation, either financially or through course credits.

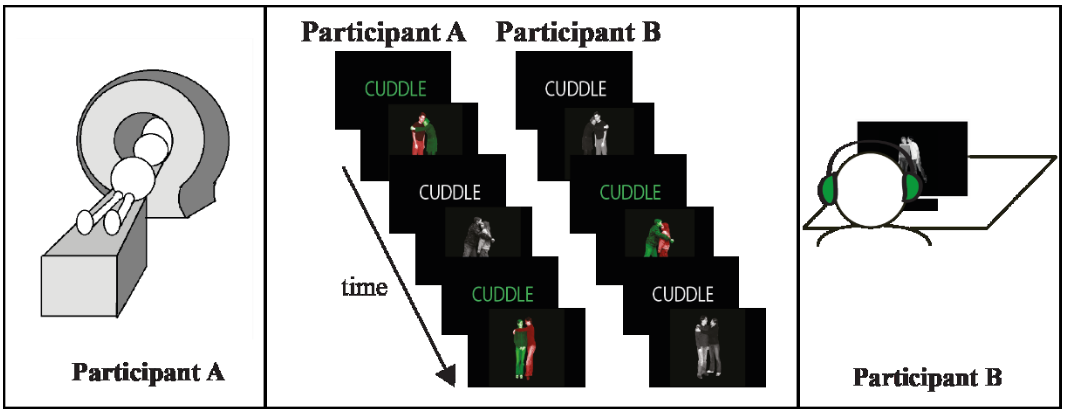

Figure 2.1. Set up of the experiment in the communicative context condition. Two participants - one in the MRI scanner, one in the behavioural experiment room - describe photographs to each other. (In the non-communicative context, there was only one - MRI - participant.) Trial structure and task were identical in both conditions. Green verbs at the start of a trial indicated that a (color-coded) production photograph would follow; grey verbs indicated a (grayscale) comprehension photograph would follow. Verbs were presented to participants in Dutch (English translation is shown in the figure). Production photographs were colour coded to guide participants' production: participants were instructed to name the green figure before the red figure, leading them to produce an active or a passive sentence. When participant A in the communicative context produces a description, participant B listens to the description, and vice versa. Mismatches in the communicative context were created by showing a different photograph to speaker and listener (in the non-communicative context, a non-matching sentence recording was played to the participant). In both contexts, the listener needs to press a button when a mismatch is noticed. Feedback screens were only present in the communicative context: they reflect the percentage of hits minus false alarms and misses by both participants. Feedback was only presented within a filler block.

2.2.2. Experimental design

Non-communicative context versus communicative context was a between-participant manipulation (factor Context). Within each level of this factor, the same 4 within-participant factors were manipulated: Syntactic Repetition (syntax was novel vs. repeated compared to the preceding sentence), Speaker Switch (same speaker vs. different speaker compared to the preceding sentence), Target Modality (participant is the speaker or the listener during the target trial) and Target Structure (active vs. passive voice). This resulted in 16 within-participant conditions. The design (8 conditions resulting from crossing three of the within participant factors, leaving out the within-participants factor Target Structure and the between-participants factor Context) is illustrated in Figure 2.2. Stimuli were presented in a running priming paradigm where each target item also served as the prime sentence for the next target item (see Figure 2.1).

2.2.3. Task

The participants' tasks during production and comprehension trials were identical in the non-communicative and the communicative context. Task-specifications as stated below can therefore also be found in Segaert et al. (2012).

During production trials, the participant's task was to describe the color-coded photographs overtly with a short sentence using the verb that was presented immediately before the photograph appeared on the screen. Participants were instructed to name the green actor before the red actor (*stop light paradigm*; Menenti et al., 2011). Other than the appearance of the photographs, there was no cue for the participants to start the description; they could freely start whenever they were ready.

During comprehension trials, a sentence-photograph matching paradigm was used (Clark & Chase, 1972). Participants were presented with a photograph and heard a description, either pre-recorded (non-communicative condition; presented following the photograph with an ISI of 0 - 1000 ms) or provided by the other participant (communicative condition). For more details on the sentence recordings that were used in the non-communicative context, see Segaert et al. (2012). Participants were instructed to press a button whenever the photograph that was presented to them did not match the description they heard.

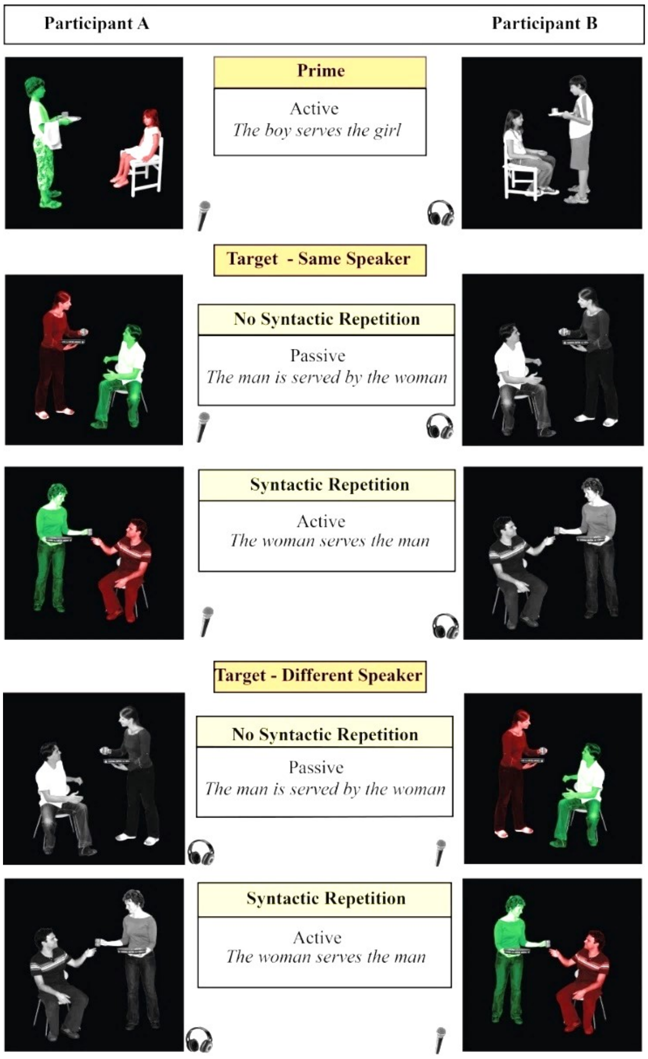

Figure 2.2. The design figure illustrates the within-subject factors. Communicative context was manipulated between subjects (in the communicative context, participants A and B speak and listen to each other; in the non-communicative context, there is only one participant). Four within-participant factors are manipulated for each level of the between-participant factor context: Syntactic Repetition (repeated or novel syntax), Speaker Switch (same speaker or different speaker), Target Modality (production or comprehension) and Target Structure (active or passive). The figure illustrates only the first three: between prime and target, syntactic structure (active or passive) and speaker could be the same or different. From the perspective of one participant, the processing modality could thus be repeated or not, with the modality of the target being comprehension or production. In both contexts, materials were presented to participants in Dutch: examples in the figure are translated to English.

2.2.4. Stimulus material

In both the non-communicative and the communicative condition, we asked participants to describe photographs, or to listen to a description of a photograph. We used identical photographs in both conditions. Therefore, the details of stimulus material as described here can also be found in Segaert et al., 2012. All photographs had been pretested previously (Menenti et al., 2011) to establish whether the depicted actions were clear and to measure which verb was most commonly used to describe the action. Due to reasons explained in Segaert et al. (2012), during the experiment this verb was presented immediately preceding the photographs for production and comprehension trials. Participants were required to use that verb in their description of the photograph. For comprehension trials, photographs were accompanied by pre-recorded descriptions in active or passive voice in the non-communicative condition. These recorded descriptions were not used in the communicative condition, as the participants listened to a real time description of the other participant (for details about the recordings see Segaert et al., 2012).

The photographs that were used to create the target trials depicted 36 different events with a patient and an agent performing an action, which can be described with a transitive verb such as 'feeding' or 'serving'. Each event was enacted by four different couples (2 man-woman and 2 boy-girl couples) and for each couple, there was one photograph with the male and one photograph with the female in the agent role. Furthermore, two photographs were made for every agent-patient combination: one with the agent on the left and one with the agent on the right. This led to 16 different photographs for each event. For each of these photographs, three versions were created to differentiate between comprehension and production targets. For comprehension trials, a grayscale version was shown. For production targets, photographs were color-coded to elicit descriptions in the passive or active voice (see section 2.2.). The active version of the photograph had a green agent and a red patient, for the passive version the actor is red and the patient is green (see examples in Figures 2.1 and 2.2).

The filler items were created with a different set of photographs. Filler items were added to provoke variability in the syntactic structures and in the lexical items that participants produced/heard during the experiment. There were photographs depicting one actor performing an action that can be described with an intransitive verb, such as ‘singing’ or ‘running’, and photographs depicting two inanimate objects or one actor and one inanimate object, the relation between which can be described with a locative verb, such as ‘standing’ or ‘lying’. Three versions were again created for each photograph: two color-coded versions for the production trials and one grayscale version for comprehension trials. For the intransitive production targets, the actor was shown in green or red. For the locatives, color-coded versions of the photographs were used to elicit a locative state ('the ball lies on the table') or a frontal locative ('on the table lies a ball'). For intransitives, the actors were sometimes famous people (e.g. former U.S. president Bush), animals, or people that could be named by their profession (e.g. the policeman).

2.2.5. List Composition

List composition was largely identical in the non-communicative and the communicative condition (details for the non-communicative condition can also be found in Segaert et al., 2012). Participants were presented with 320 target items (20 items in each of the 16 conditions). In addition to this, there were 80 transitive structure items that serve as prime-only items at the beginning of target blocks. This increases the total number of items in target blocks to 400. Target items were presented in 80 blocks with an average length of 5 transitive structures (range 3 - 7 items). The verb was always repeated between the items in one target block. The conditions followed each other in a random order that was different for every participant, with two constraints on the order of conditions. The first is that no condition is repeated twice in a row and the second is that a target item with adults is always followed by an item with children and vice versa, so that there was no lexical repetition between items other than the verb. In a full list of items presented to the participant, the same action or the same actors could occur several times, but the combination of actors and actions was unique. Target blocks were alternated with filler blocks. Since in target blocks the verb was always repeated between items, the verb was also repeated between filler items within one block. For 10% of the filler items, this was not the case to bring in some extra variation. There were 280 filler items, divided over 80 blocks (2-5 filler items per block, average length of 3.5). Each participant thus received 680 trials in total (320 targets, 80 prime-only and 280 filler trials), which were divided over 2 scanning sessions (45 minutes each). Each photograph could occur only once in the experiment and every participant saw a different list of items.

In the non-communicative condition, 10% of the filler items consisted of a mismatch between the photograph that the participant saw and the recorded sentence that the participant heard. For example, while seeing a photograph that depicted a man kissing a woman, the participant could hear: "the man punishes the woman" or "the woman kisses the man". In these cases, participants had to press a button. In the communicative condition, mismatches were created by showing a different photograph to the participants (see Figure 2.1). Thirty-five percent of the filler items in the communicative context were intended mismatches. Only half of the mismatches in the communicative context (17,5%) needed to be detected by the fMRI participant though (i.e. a mismatch between the fMRI comprehension trials and the behavioural production trials). The other half needed to be detected by the behavioural participant (behavioural comprehension trials - fMRI production trials). This mismatch percentage for the fMRI participant in the communicative condition was increased relative to the non-communicative condition to make the feedback percentages (see below) more variable. For both contexts, there were mismatches between photograph and description for transitive photographs (50% of all mismatches) and intransitive/locative photographs (50% of all mismatches). Additionally, participants in the communicative condition also created their own mismatches when the speaker gave a wrong description of the photograph. No mismatch trials were included in the analyses.

In the non-communicative context, the detection-rate of the mismatches was used to check whether participants pay attention during comprehension: syntactic and semantic processing was necessary to detect these mismatches. In the communicative condition mismatch-trials have an additional function: since it depends on both participants whether the mismatch is correctly detected, the detection-rate is a good measure of how well participants are working together.

Mismatches can therefore be used to enhance the feeling of having a shared communicative goal. We increased this feeling in two ways. First, participants heard a beep whenever one of them pressed a button. That way, they both knew a mismatch was detected by the participant that saw a comprehension trial. Second, visual feedback was provided, which showed a percentage that indicated how well participants were performing the task. This percentage was based on the mismatches that were not correctly detected (misses), but also on false alarms: participants pressing the button when there was no mismatch between photographs. Errors can arise due to either participant, the speaker can make a mistake during photograph description; the listener can fail to detect a description mistake or can incorrectly detect a description mistake. Thus, the participants' joint effort is reflected in the feedback percentages. Participants saw a feedback screen 26 times during the entire experiment. These feedback trials were always presented within a filler-block, but not after the final item of this block (i.e. not directly preceding a prime). So, every third filler-block participants were presented with feedback.

2.2.6. Trial structure & Procedure

Trial structure was identical in both conditions (see also Segaert et al., 2012, for the non-communicative context only). Each trial started with the presentation of the verb. This verb was color-coded to let the participants know whether a "comprehension photograph" or a "production photograph" would follow. Green verbs preceded production photographs and grey verbs preceded comprehension photographs. When one participant in the communicative condition (fMRI/behavioural) saw a green verb, introducing a production photograph, the other participant saw a grey verb, after which a comprehension photograph would follow. After presentation of the verb (500 ms) and an ISI of 500-2500 ms, a photograph (in colour for production trials, grey for comprehension trials) was shown for 2000 ms before the screen turned black.

Before starting the experiment, participants read instructions on paper and the experimenter checked whether they understood everything. In the communicative context condition, the experimenter flipped a coin to decide which of the two participants would perform the experiment in the MRI scanner. We included this procedure to make sure participants were convinced of working with another naive participant, rather than a confederate. Hereafter, one participant was placed in the MRI scanner and the other was installed in a separate, quiet room.

Participants completed a short practice block before the actual experiment started. After the practice trial, they had the opportunity to ask questions. Furthermore, in the communicative context condition, both participants were asked whether they could hear each other well. The experiment consisted of 2 runs of 45 minutes, both in the communicative and the non-communicative context. Between the two runs, fMRI participants underwent an anatomical T1 scan. All participants then got a short break outside the MRI scanner/experiment room. After the experiment there was a debriefing during which all participants in the communicative context indicated that they believed that they were interacting with another participant and not a confederate.

2.2.7. fMRI Data Acquisition

Acquisition parameters in the non-communicative and communicative context condition were identical: this section is therefore identical to the data acquisition section in Segaert et al. (2012). Participants were scanned with a Siemens 3-T Tim-Trio MRI scanner, using a 12-channel surface coil. To acquire functional data, we used parallel-acquired inhomogeneity-desensitized fMRI (Poser et al., 2006). This is a multiecho echo-planar imaging sequence, in which images are acquired at multiple time echoes (TEs) following a single excitation (time repetition [TR] = 2.398 s; each volume consisted of 31 slices of 3 mm thickness with slice gap of 17%; isotropic voxel size = 3.5 3 3.5 3 3 mm3; field of view [FOV] = 224 mm). The functional images were acquired at following TEs: TE1 at 9.4 ms, TE2 at 21.2 ms, TE3 at 33 ms, TE4 at 45 ms, and TE5 at 56 ms, with echo spacing of 0.5 ms. This entails a broadened T2* coverage because T2* mixes into the 5 echoes in a different way, and the estimate of T2* is improved. Accelerated parallel imaging reduces image artefacts and thus is a good method to acquire data when participants are producing sentences in the scanner (causing motion and susceptibility artefacts).

However, the number of slices did not allow acquisition of a full brain volume in most participants. We made sure that the entire temporal and frontal lobes were scanned because these were the regions where the fMRI adaptation effects of interest were expected. This meant that data from the superior posterior frontal lobe and the superior parietal lobe (thus data from the top of the head) were not acquired in several participants. A whole-brain high-resolution structural T1-weighted magnetization prepared rapid gradient echo sequence was performed to characterize participants' anatomy (TR = 2300 ms, TE = 3.03 ms, 192 slices with voxel size of 1 mm3, FOV = 256), accelerated with GRAPPA parallel imaging.

2.2.8. Data analysis

2.2.8.1. Behavioural data analysis

The experimenter coded production responses of the participants online for correctness. Target trials were considered for analysis if during both prime and target trial 1) the correct structure was used and 2) both actors were named accurately and the presented verb was used correctly (88.25% of all target trials). To be able to make audible recordings (and for the behavioural participant to be able to hear the fMRI participant), we made use of a noise-cancellation microphone inside the MRI scanner, which filtered out most of the noise made by the scanner. For each trial an individual recording started from the onset of the photograph on the screen. From these recordings, speech onset latencies were automatically determined. First, MRI scanner noise was filtered out by the use of a band pass filter (250 -2500 Hz), before smoothing the signal and conversion to z-scores. We then set a threshold above which the signal could reliably be identified as speech. The same threshold was used for all sound files. Before analyses, onsets that were smaller than 300 ms were excluded from the raw data (0.07% of all correct target trials). Averages and standard deviations were then calculated per participant per condition. Onsets that were more than 2.5 standard deviations away from this participant by condition mean were excluded from further analysis (1.92% of all correct target trials).

Two analyses were carried out using the speech onset data. The first, between-context analysis was done to test our first hypothesis that syntactic priming effects are stronger in a communicative context. We separated the behavioural and the MRI participants in the communicative context to assess whether MRI and behavioural participants would show identical reaction time patterns. A repeated measures ANOVA was carried out with SPSS, with within-participant factors Syntactic Repetition, Speaker Switch, Target Modality and Target Structure, and between-participant factor Group (communicative-behavioural, communicative-MRI and non-communicative-MRI). The second analysis on the behavioural data concerned our second hypothesis. A within-context correlational analysis was carried out on the syntactic priming effects of the MRI and behavioural participants in the communicative condition, also using SPSS, to see whether priming effects correlate within participant pairs (i.e. between the MRI and behavioural participant). For the latter analysis, we split the priming effects into between-participants (i.e. comprehension to production) priming effects and within-participants (i.e. production to production) priming effects, and performed separate, identical analyses for both datasets. The reason for this split was that if participants indeed accommodate to each other and their priming effects are correlated, this effect will be strongest for between-participant priming, and weaker (or even non-existent) for within-participant priming effects.

2.2.8.2. fMRI data analysis

Pre-processing

For both contexts, fMRI data were pre-processed as described in Segaert et al., 2012, using SPM5 (Friston et al., 2007). The first 5 images were discarded to allow for T1 equilibration. Then the 5 echoes of the remaining images were realigned to correct for motion artefacts (estimation of the realignment parameters is done for one echo and then copied to the other echoes). The 5 echoes were combined into one image with a method designed to filter task correlated motion out of the signal (Buur et al., 2009)). First, echo 2--5 (i.e., TE2, TE3, TE4, and TE5) were combined using a weighting vector with the weights depending on the measured differential contrast to noise ratio. The time course of an image acquired at a very short echo time (TE1) was then used in a linear regression as a voxel wise regressor for the other image (i.e., the result of combining TE2, TE3, TE4, and TE5) in the same echo train acquired with high BOLD sensitivity. The resulting images were coregistered to the participants' anatomical volume, normalized to Montreal Neurological Institute space, and spatially smoothed using a 3D isotropic Gaussian smoothing kernel (full-width at half-maximum = 8 mm).

Whole brain analysis

All fMRI analyses were performed in order to compare participants in the communicative condition with the participants in the non-communicative condition. As said above, the data from the non - communicative context had already been collected for the Segaert et al. (2012) experiment. First- and second-level statistics were performed using the general linear model framework of SPM5 (Friston et al., 2007). One main regressor contained information about the between-participant factor Context (communicative or non-communicative). Within each level of Context there were 16 main regressors coding for the 16 conditions resulting from the 2 x 2 x 2 x 2 design with within-participant factors Syntactic Repetition, Target Modality, Speaker Switch and Target Structure. An explicit baseline (fMRI measurements during the presentation of verbs) was used. In the first-level linear model, we modelled the individual start time of the photograph during production trials or the start time of the pre-recorded utterance (non-communicative context) or the 'live' description (communicative context) during comprehension trials. We modelled the hemodynamic response function only as related to these onsets and set the duration as a constant event. Separate regressors were included for the verbs, photographs during comprehension trials, filler items, items which were only primes, and incorrect responses. The events of the model were convolved with the canonical hemodynamic response function provided by SPM5. Also the temporal derivatives were included in the model. Furthermore, 6 motion parameters (realignment parameters: translation along, and rotation around, the x, y, and z axes) and 2 parameters which correct for global intensity fluctuations (compartment signal parameters: white matter and cerebral spinal fluid; Verhagen et al., 2008) were added as regressors. For the second-level random-effects analysis, we used the beta-images of the 16 main regressors for each condition, leading to a total of 32 main regressors in the second level between-context model. The cluster size was used as the test statistic and only clusters significant at $P < 0.05$ corrected for multiple non-independent comparisons are reported. Local maxima are also reported for all clusters with their respective Z values.

Region of Interest analyses

Two Region of Interest (ROI) analyses were performed. We opted for this approach because we expect to find differences between participants in the two contexts in regions related to syntactic processing. ROI analyses then allow us to check for interactions with more sensitivity than whole brain analyses. There were two sets of ROIs. The first set of ROIs corresponded to the activation clusters for which a main effect of Syntactic Repetition was found in the whole-brain analysis. A second ROI-analysis was done based on regions in which significant syntactic priming effects were reported previously for production and comprehension: the left inferior frontal gyrus and in the left posterior middle temporal gyrus (Menenti et al., 2011). For each cluster, average time courses were calculated using Marsbar (http://marsbar.sourceforge.net/). For the ROI analysis at the second level, a repeated measures analysis of variance was carried out with the factors Region, Syntactic Repetition, Speaker Switch, Target Modality, Target Structure and Context on the subject contrast values using SPSS. The aim of both of these analyses was to establish with higher sensitivity whether there were interactions with the factors Syntactic Repetition and Context. Interactions of interest were Syntactic Repetition * Context (* Region) and Syntactic Repetition * Context * Speaker Switch (* Region). The latter interaction is interesting because the effect of communicative context may be more pronounced for between-speaker priming (Speaker Switch) than for within-speaker priming (No Speaker Switch).

2.3. Results

2.3.1. Task performance (accuracies)

Participants from all three groups (fMRI non-communicative - N=24, fMRI communicative - N=24, behavioural communicative- N=24) performed equally well on the production and comprehension task. In the production task, fMRI participants responded correctly on 96% of the trials in the non-communicative context and on 98% of the trials in the communicative context condition. For the comprehension task, the average d-prime for fMRI participants was 0.91 in the non-communicative context condition and 0.88 in the communicative context condition. A t-test revealed no difference between the two MRI groups on their performance ($p > 0.1$). For the behavioural participants, the average d-prime was 0.87. Performance of participants within one pair did not differ significantly ($p > 0.7$).

2.3.2. Hypothesis 1 - Is syntactic priming stronger in a communicative context? Between-context analyses (non-communicative vs. communicative context) in behaviour and brain

In this section, we report the results of the analyses that we did to test the hypothesis that syntactic priming effects are stronger in a communicative context. That is, we compare the magnitude of syntactic priming effects between participants in the non-communicative and the communicative condition. The results of three analyses are reported: one with respect to participants' behavioural results (speech onset latencies) and two with respect to their brain results (fMRI adaptation effects on the whole brain and ROI level). For the comparison of behavioural effects, we included all three participant groups (MRI and behavioural participants in the communicative context). For the comparison of syntactic priming effects in the brain, naturally, only the participants in the two MRI groups are taken into account.

2.3.2.1. Behaviour (speech onset latencies)

In this analysis, we compared behavioural syntactic priming effects of the participants in the communicative context (in the MRI scanner and in the behavioural experiment room) to the syntactic priming effects of participants in the non-communicative context. We ran a repeated measures ANOVA with the factors Syntactic Repetition, Speaker Switch, Target Structure and Group (communicative-behavioural, N=24 communicative-MRI, N=24 and non-communicative-MRI, N=24). Results from this analysis showed a significant effect for Syntactic Repetition ($mean_{No\text{-}Repetition}$ = 1065.9 ms, SE = 24 ms, $mean_{Repetition}$ = 1031.3 ms, SE = 23 ms, $F(1,69) = 30.34$, $p < 0.001$), Target Structure($mean_{Active}$ = 998.4 ms, SE = 22 ms, $mean_{Passive}$ = 1098.9 ms, SE = 26 ms, $F(1,69) = 126.62$, $p < 0.001$), Speaker Switch ($mean_{NoSwitch}$ = 1054.8 ms, SE = 24 ms, $mean_{Switch}$ = 1042.4 ms, SE = 22 ms, $F(1,69 = 4.01$, $p < 0.05$) and Group ($mean_{Communicative\text{-}Behavioral}$ = 962 ms, SE = 27 ms, $mean_{Communicative\text{-}MRI}$ = 1096 ms, SE = 27 ms, $mean_{NonCommunicative\text{-}MRI}$ = 1087 ms, SE = 39 ms, $F(2,69) = 3.77$, $p < 0.03$). The main effect of Syntactic Repetition indicates that the speech onset latencies show a syntactic priming effect. Crucially, there was no two-way interaction between Syntactic Repetition and Group ($F(2,69) = 0.884$, $p > 0.4$). Results did show a significant interaction between Speaker Switch and Syntactic Repetition ($F(1,69) = 8.64$, $p < 0.005$). Follow-up tests showed that for all groups, the syntactic priming effect was largest when target and prime were produced by the same speaker. The difference lies in the novel syntax condition. When having produced the prime themselves, speakers are slower to produce a sentence with a novel syntax than when the prime was produced by a different speaker ($p < 0.01$). In the repeated syntax condition, there was no difference between the two speaker switch conditions ($p > 0.8$). There was also a significant 4-way interaction between Speaker Switch, Syntactic Repetition, Target Structure and Group ($F(2,69) = 3.35$, $p < 0.05$). Follow-up tests on the latter interaction revealed that the three groups differed from each other in the condition where there has been a speaker switch between prime and target, and the target is a passive structure ($F(2,69) = 4.21$, $p < 0.02$). For both of the MRI groups, there was no effect of Syntactic Repetition in this condition ($p > 0.05$) whereas there was for the behavioural participants in the communicative context ($p < 0.05$).

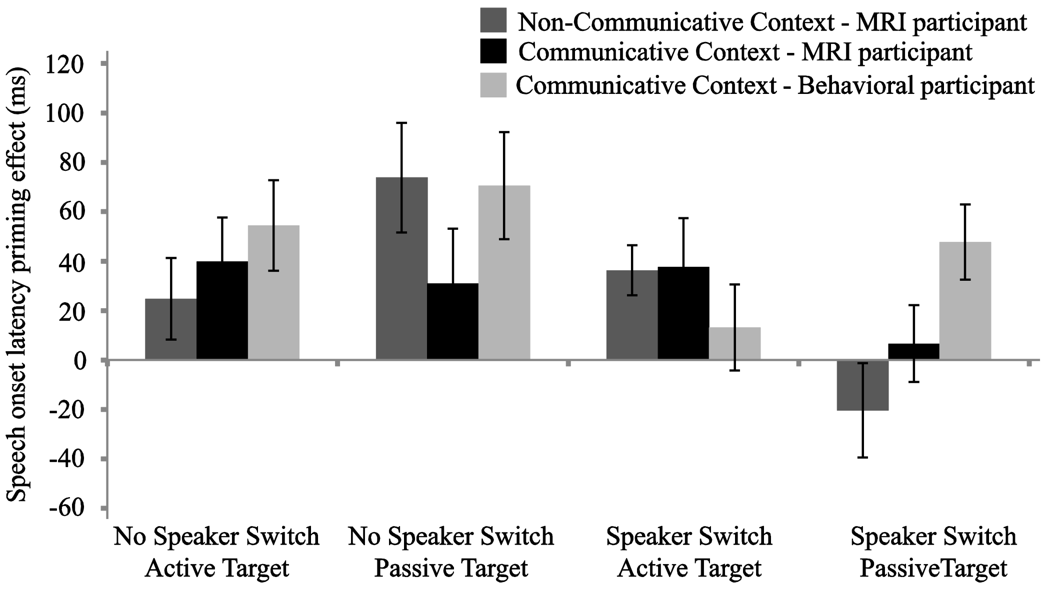

Figure 2.3. Between-context analysis (1): behavioural results for three groups of participants. Speech onset latency-priming effects (novel - repeated syntax) in ms (error bars reflect standard errors), split by Speaker Switch (no speaker switch means production prime - production target; speaker switch means comprehension prime - production target) and Target Structure (active or passive voice). Dark-grey bars represent the average priming effect of the MRI participants in the non-communicative condition. Black bars represent the MRI participants in the communicative context and the lighter grey bars represent behavioural participants in the communicative condition. There were speech onset latency-priming effects in the two communicative as well as in the non-communicative condition. The groups differed from each other in the Speaker Switch - Passive target condition, in that only the behavioural participants in the communicative context showed a significant priming effect here. There was no overall interaction Syntactic Repetition * Group: it is not the case that participants in the communicative context show stronger syntactic priming effects than participants in the non-communicative context.

2.3.2.2. Brain (fMRI adaptation effects)

Whole brain analysis

For the whole brain analysis, we used an uncorrected voxel wise threshold of $p < 0.001$ and a cluster-level threshold corrected for multiple comparisons of $p < 0.05$. As displayed in Figure 2.4 and Table 2.1, there were several regions showing a repetition suppression effect to repeated syntax (conditions with novel syntax minus conditions with repeated syntax): left insula extending into left inferior frontal gyrus (BA 47 and BA 45), left middle temporal gyrus extending into inferior temporal cortex (BA 21 and BA 37), left inferior parietal cortex extending into superior parietal cortex (BA 40 and BA 7), left precentral gyrus (BA 6), bilateral precuneus (BA 7), bilateral supplementary motor area extending into right anterior cingulum (BA 32/8 and BA 32), and right insula (BA 47). These regions are thus less activated for sentences with a repeated syntax than for sentences with novel syntax; they show repetition suppression for syntax. There were no repetition enhancement effects. At the whole-brain level, there were no regions that showed significant interactions between Syntactic Repetition and Context (i.e. more repetition suppression for communicative context) or between Syntactic Repetition, Context and Speaker Switch (i.e. more repetition suppression for communicative context in the conditions where the prime speaker is not the same as the target speaker; production prime - comprehension target and comprehension prime - production target).

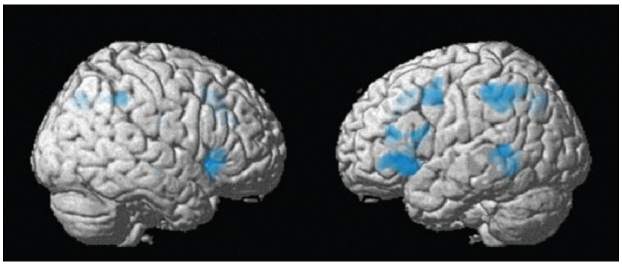

Figure 2.4. Between-context analysis (2): whole-brain results (see also Table 2.1). In the left insula extending into left inferior frontal gyrus (BA 47/45), left middle temporal gyrus (BA 21), left inferior parietal cortex (BA 40), left precentral gyrus (BA 6), bilateral precuneus (BA 7), bilateral supplementary motor cortex (BA 32/8) and right insula (BA 47), there was a repetition suppression effect for repeated compared to novel syntactic structures, in the communicative as well as the non-communicative condition.

Table 2.1. fMRI results. Main effect Syntactic Repetition, interaction Syntactic Repetition * Context and Syntactic Repetition * Context * Speaker Switch

Anatomical Label	BA	Global and local maxima			Cluster-level		Voxel-level
		X	Y	Z	K	P(corr)	Z
Main effect Syntactic Repetition (No syntactic repetition > Syntactic Repetition)							
L. Inferior Parietal	40	-42	-44	40	928	<.001	5.37
L. Inferior Parietal	40	-52	-36	46			4.68
L. Superior Parietal	7	-32	-62	48			3.54
L. Precentral	6	-38	2	44	424	<.001	5.16
L. Precentral	6	-46	0	42			4.30
L. Precentral	6	-46	8	42			4.20
L. Precuneus	7	-6	-70	40	333	<.002	5.02
R. Precuneus	7	8	-72	40			3.71
R. Precuneus	7	14	-58	42			3.56
L. Supp. Motor Area	32/8	-8	22	46	408	<.001	4.98
R. Supp. Motor Area	32/8	6	18	48			4.19
R. Anterior Cingulum	32	14	36	26			3.33
L. Insula	47	-38	20	-6	895	<.001	5.18
L. Inferior Frontal Pars. Orb.	47	-32	30	-4			4.69
L. Inferior Frontal Pars. Tri.	45	-48	34	0			3.85
L. Middle Temporal	21	-50	-44	2	387	<.001	4.54
L. Middle Temporal	21	-54	-46	4			4.33
L. Inferior Temporal	37	-58	-54	-6			3.64
R. Insula	47	36	24	0	452	<.001	4.98
Interaction Syntactic Repetition * Context							
No significant clusters							
Interaction Syntactic Repetition * Context * Speaker Switch							
No significant clusters							

ROI analyses

To maximize detection power, we also investigated possible interactions between the factors Syntactic Repetition and Context in ROI analyses. The sensitivity on the whole-brain level may have been insufficient to detect interactions with a between-group factor. ROI analyses allow searching for potential interactions between syntactic repetition and context at the highest possible statistical sensitivity. Analyses of variance were carried out with the within-participant factors Region, Syntactic Repetition, Speaker Switch, Target Modality and Target Structure and the between-participants factor Context.

The first ROI-analysis included the 7 regions that were derived from the clusters that showed significant repetition suppression effects for syntax in the whole brain analysis reported above. There were no interactions between Syntactic Repetition and Context: the interactions Syntactic Repetition * Context (*Region) and Syntactic Repetition * Speaker Switch * Context (*Region) were not significant in this analysis (all $p > 0.1$).

We also performed a second ROI analysis in two pre-defined regions; the left inferior frontal gyrus and the left posterior middle temporal gyrus (clusters based on Menenti et al., 2011). Although there were significant main effects for repetition in both regions (left inferior frontal gyrus: $p < 0.01$; left posterior middle temporal gyrus: $p < 0.005$), again, there were no significant interactions between Syntactic Repetition * Context or Syntactic Repetition * Speaker Switch* Context (all $p > 0.7$). Interactions with repetition that were significant were Target Modality * Speaker Switch * Repetition in left inferior frontal gyrus ($p < 0.02$) and Target Modality * Repetition in left posterior middle temporal gyrus ($p < 0.02$).

In sum, even with the increased detection power of ROI analyses, and in two different ROI analyses, we did not find evidence that the repetition suppression effects for syntactic repetition differ between the communicative and non-communicative context.

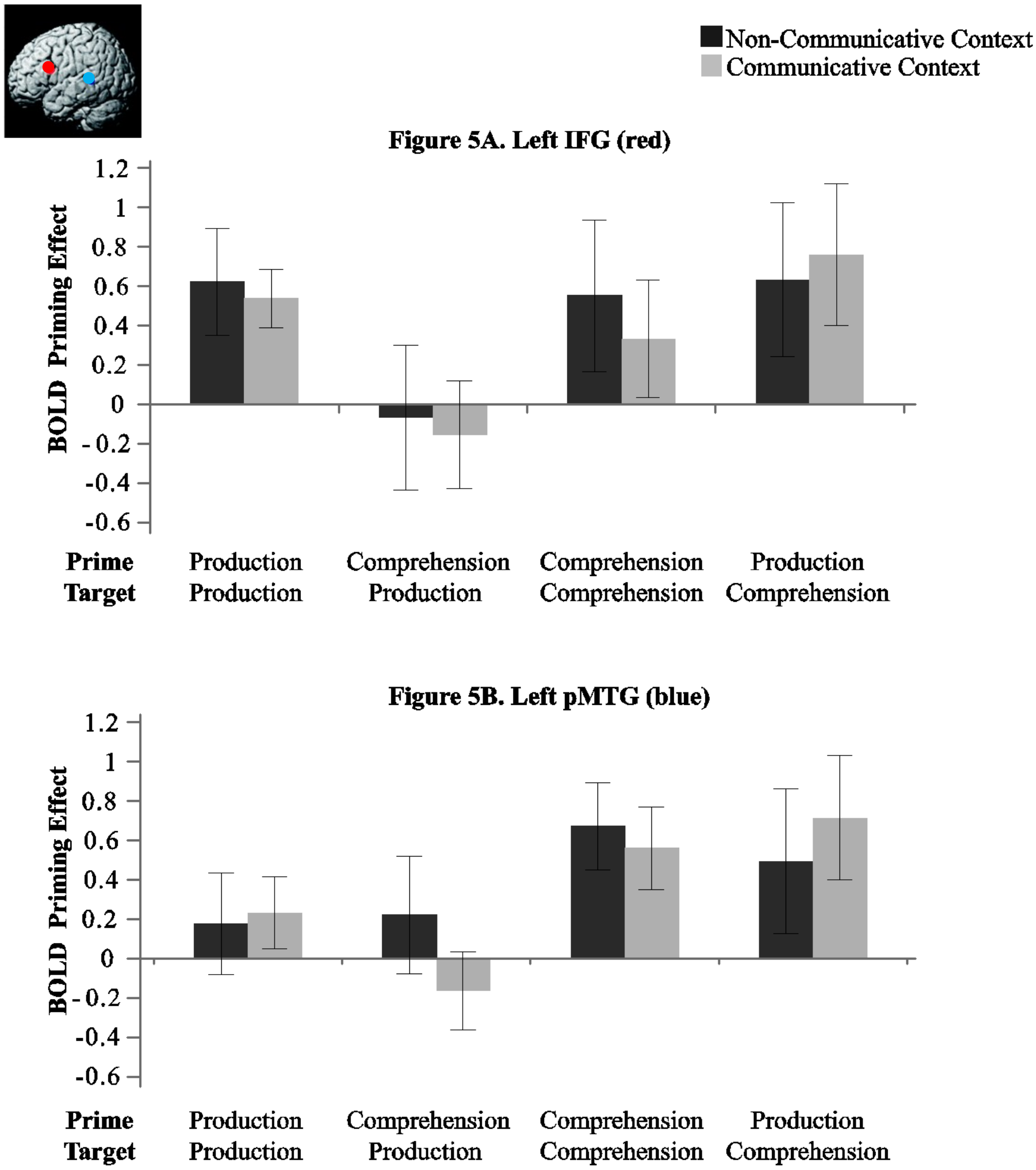

Figure 2.5. Between-context analysis (3): ROI-analyses in two clusters based on Menenti et al. (2011): left inferior frontal gyrus (top) and left pMTG (bottom). Error bars reflect standard errors. There is a main effect of Syntactic Repetition in both clusters but no interaction with Context: participants in the non-communicative and communicative condition do not differ in the strength of their repetition suppression effects in these regions.

2.3.3. Hypothesis 2 - Is syntactic priming in communication influenced by the interlocutor's behaviour? Within-Context (communicative context only) analysis in behaviour

In this section, we report the results of the analysis that we did to test the second hypothesis that the syntactic priming effects of one speaker in a communicative pair are influenced by the syntactic priming effects of the other speaker in that pair. This analysis is done for the participants in the communicative context only: we correlated the behavioural (speech onset latency) priming effects of the MRI and the behavioural participants who were paired.

2.3.3.1. Correlation analysis between two interlocutors in the communicative context

There was a significant positive correlation between the average behavioural priming effect (speech onset syntax not-repeated – speech onset syntax repeated) of the MRI participants and the average priming effect of the behavioural participants over trials in which participants were primed by each other ($r=0.382$, p (one-tailed) < 0.04). The stronger the priming effects for the MRI participant when the prime is provided by the behavioural participant, the stronger the priming effects for the behavioural participant when the prime is provided by the MRI participant. As a control, this correlation was not significant for the average priming effects over trials where the participants were not primed by the other participant but primed by themselves ($r= -0.189$, p (one-tailed) > 0.15). Thus, when a speaker is primed by another person, the average syntactic priming effect of this interlocutor in the conversational pair is influenced by the average syntactic priming effect of the other interlocutor in that pair.

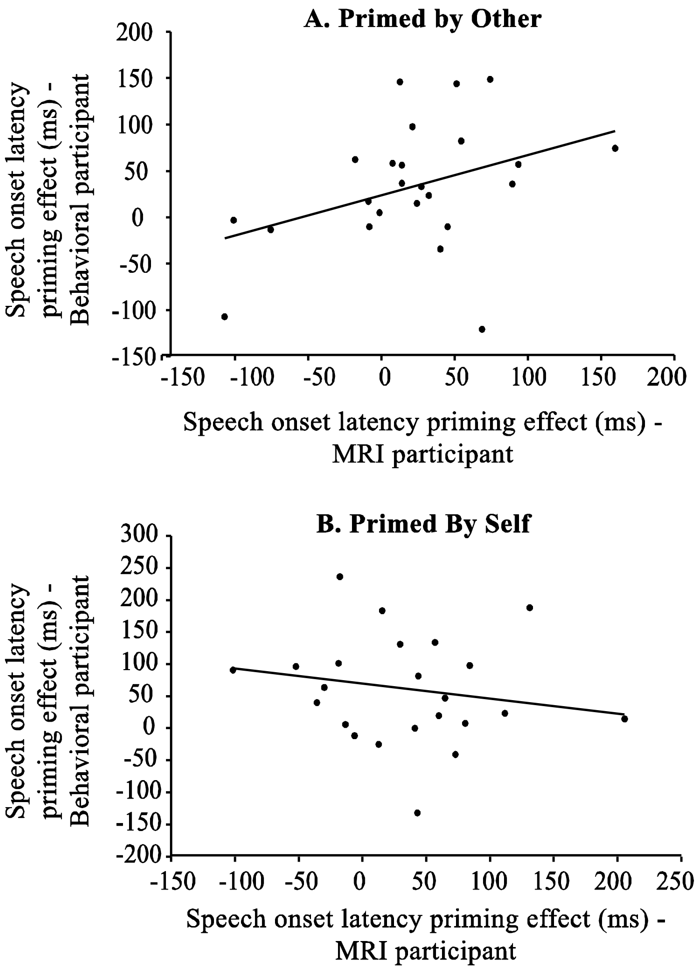

Figure 2.6. Within-context analysis: correlation between individual magnitudes of syntactic priming effects (repeated - novel syntax) in speech onset latencies (ms) for the participants in the communicative context. The Y axis represents the average syntactic priming effect of the behavioural participant, the X axis the average syntactic priming effect of the participant in the MRI scanner. Priming effects are spit according to Speaker Switch: (**A**) shows the correlation between priming effects when participants are primed by their partner (Speaker Switch - comprehension to production priming), (**B**) shows the correlation for trials where participants are primed by themselves (No Speaker Switch / production to production priming). When primed by the other participant, there is a positive correlation between the priming effects of participants in a communicative pair, whereas there is no significant correlation between participants when they are primed by themselves.

2.3.3.2. Additional evidence: exploratory analyses

Although the correlation presented above shows that speakers in a communicative pair are influenced by their interlocutor, this correlation is based on individuals' average syntactic priming effects across the entire experiment. However, if speakers indeed adapt their syntactic priming effects to their interlocutor, it is likely that individual syntactic priming magnitude changes over time. Speakers have to be exposed to their interlocutor's linguistic behaviour (in this case, to their syntactic priming magnitude) before they can adapt their own behaviour accordingly. The present experiment was not designed to investigate how syntactic priming effects change over time. However, due to the fact that participants got a break in the middle of the experiment, we could compare speakers' behaviour in two consecutive sessions (i.e. two halves of the experiment). Because we find the correlation only for between-speaker priming, in the exploratory analyses presented below, we only take between-speaker priming effects into account.

If individual syntactic priming effects change over time with the (unconscious) goal to adapt one's own priming effects to the interlocutor, we expect that the syntactic priming effects of two speakers in a communicative pair become more similar over time. In other words, we would expect that the *difference* between paired individuals' syntactic priming effects (priming effect speaker A – priming effect speaker B) decreases over time. Our data seem to be in line with this: an exploratory paired samples t-test showed that on average, the difference between paired individuals' syntactic priming effects decreases between session one (mean difference = 106.13 ms, SE = 17.88 ms) and session two (mean difference = 70.23 ms, SE = 8.83 ms; $t\ (23) = 1.85$, $p < 0.08$). Furthermore, we see that the variance between pairs decreases between sessions ($F\ (1,46) = 6.68$, $p < 0.02$). So, we do not only see that within pairs, the difference between individuals' syntactic priming effects decreases between sessions, but also that the variance between pairs - with respect to this difference - decreases. Therefore, we would expect that the strength of the decrease in the difference between individual's syntactic priming effects will be proportional to how different they are at the start of the experiment. A final, correlational analysis provides further support for this: the more different syntactic priming effects of individuals in a communicative pair are at the start of the experiment (here: session one), the more this difference will decrease over time (here: between session one and session two; r = -0.891, $p < 0.001$).

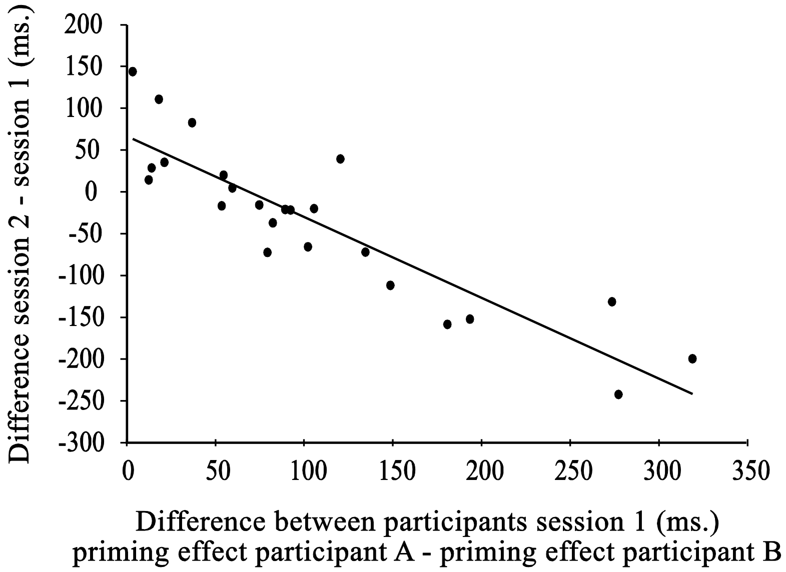

Figure 2.7. Correlation between the difference between paired participants' syntactic priming effects in session one of the experiment (x-axis: priming effect speaker A - speaker B) and the decrease / increase of that difference over time (y axis: difference part two - difference part one). So, the more different paired individual's syntactic priming effects are in session one of the experiment, the more this difference will decrease between session one and session two.

2.4. Discussion

In this study, we investigated whether syntactic processing during overt production and comprehension is subject to the top-down influence of being in a communicative context, i.e. having or sharing the intention to communicate. Specifically, we examined whether communicative context influences the magnitude of syntactic priming effects. Before addressing this issue, though, we first established that there were syntactic priming effects both in behaviour and in the brain in both the non-communicative and communicative context. In behaviour we found that speakers are faster to start producing sentences with a repeated syntax compared to sentences with a novel syntax. In the brain we found that during production as well as comprehension brain activation is suppressed for sentences with repeated syntax compared to sentences with novel syntax (i.e. repetition suppression) in regions associated with syntactic processing and its downstream consequences (left insula extending into left inferior frontal gyrus (BA 47/45), left middle temporal gyrus (BA 21), left inferior parietal cortex (BA 40), left precentral gyrus (BA 6), bilateral precuneus (BA 7), bilateral supplementary motor cortex (BA 32/8) and right insula (BA 47)). We then tested two specific hypotheses with regards to the nature of the influence of communicative context on the magnitude of syntactic priming effects. Our first hypothesis was that priming effects are a way for speakers to adapt to the needs and expectations of their conversational partners. If so, the presence of a communicative context should increase syntactic priming effects: if you want to communicate something, you are more likely to adapt to the other person than if you do not have such an intention. To test this prediction, we compared the syntactic priming effects of participants in a communicative context (i.e. two participants addressing each other) to the effects of participants doing the same experiment in a non-communicative context (i.e. speaking without having a direct addressee and listening without being addressed directly). Both with respect to behaviour (speech onset latencies) and brain activations (repetition suppression effects on whole-brain and ROI-level), our results did not support the first prediction: participants did not show stronger syntactic priming effects in a communicative context. We did find support for the second hypothesis we put forward: the magnitude of speakers' syntactic priming effects is influenced by the magnitude of the priming effects of their interlocutor. The correlation we found between individual between-speaker syntactic priming effects of two participants within one communicative pair showed that their syntactic priming magnitudes are related: if participant A is strongly/weakly primed by participant B, then participant B is also strongly/weakly primed by participant A.

The absence of evidence in favour of our first hypothesis should be interpreted with caution, like any null-result should. Below, we consider some aspects of our design that may have confounded our results and obscured the difference between priming effects in the non-communicative and the communicative condition. First, however, we will discuss the outcomes of our analyses in more detail to get a better understanding of whether the results we do observe are in line with previous studies.

In behaviour we found that syntactic repetition speeds up production. This is in line with previous reports on syntactic priming in production latencies (Corley & Scheepers, 2002; Segaert et al., 2011; Smith & Wheeldon, 2000; Wheeldon & Smith, 2003; Wheeldon et al., 2011). We furthermore observed that the behavioural syntactic priming effects were stronger in the within-participant priming condition (no speaker switch between prime and target) than in the between-participant priming condition (speaker switch between prime and target). These findings are in line with results from a corpus study by Gries (2011) who reports that speakers' tendency to repeat syntax increases for within-speaker priming, relative to between-speaker priming. We also observed that for the speaker switch condition, the syntactic repetition effect for passives depended on whether the participant that produced the target was performing the experiment lying in the MRI scanner (in the non-communicative or communicative context) or not (behavioural participants in the communicative context). Only the participants in the communicative-behavioural condition showed syntactic priming effects for these particular targets, whereas the two MRI groups did not. Although we have no definite explanation as to why the two groups of MRI participants did not show a significant syntactic priming effect for passives when a speaker switch has taken place, literature on syntactic priming effects in production latencies has shown that this type of syntactic priming effect is more reliably found for actives than passives (see Segaert et al. (2011) for an account).

Our neuroimaging results also closely relate to the literature on syntactic priming and syntactic processing. As syntactic priming facilitates syntactic processing, we expected a modulation of the BOLD-response in syntactic processing areas. Indeed, of the brain regions in which repetition suppression effects were found, the left inferior frontal gyrus and left middle temporal gyrus are considered core syntactic processing areas (Indefrey et al., 2001; Griffiths et al., 2013; Haller et al., 2005; Menenti et al., 2012; Snijders et al., 2009). The other regions that showed significant repetition suppression effects in our study are not always considered to be core regions in the syntactic processing network, but all of these individual regions have been found to be activated together with the left inferior frontal gyrus and left middle temporal gyrus in studies aimed at identifying the syntactic processing network: left inferior parietal cortex (Haller et al., 2005; Menenti et al., 2012) left precentral gyrus (Menenti et al., 2012), bilateral precuneus (Segaert et al., 2013), bilateral supplementary motor cortex (Segaert et al., 2012) and the right insula (Haller et al., 2005). Therefore, we feel assured that we are looking at the syntactic processing network and its downstream consequences in the human brain.

Due to the fact that our analyses do show syntactic priming effects in behaviour and in the brain which are in line with the literature, we feel confident that the absence of evidence in favour of a modulation by communicative vs. non-communicative context is not a fluke. However, we do acknowledge that some aspects of our experimental design may have obscured the difference between the non-communicative and the communicative context.

Firstly, theories proposing that syntactic priming has a communicative function (Jaeger & Snider, 2013; Pickering & Garrod, 2004) refer to speakers' production choices for a particular syntactic structure relative to a constructional alternative. In our experiment, however, we did not give speakers a choice between syntactic structures. The reason for this was that for reliable fMRI analyses, many trials are needed for each condition. This number is much higher than the occurrence of passives in a free-choice experiment. Therefore, we opted for the design described above. However, we believe that this did not affect our results, as we do find significant priming effects in this type of design, both in behaviour and in the brain. Moreover, we find a top-down effect of communicative context on the magnitude of these priming effects, as evidenced by the correlation between the magnitude of syntactic priming effects of two participants in a communicative pair. Therefore, we believe that the lack of difference between participants in the communicative and the non-communicative context is not due to the way we opted to measure syntactic priming effects.

Second, we may not find a difference between syntactic priming effects in a non-communicative and a communicative context because the difference between these contexts may not have been strong enough. Several factors may have contributed here. One is that the recordings that were used in the non-communicative context condition were as natural as possible. Perhaps a less natural, more computerized recording could have increased the difference between contexts and thus could have influenced the magnitude of priming effects. Another factor is that it might be possible that the participants may have unconsciously considered the experimenter to be their addressee in the production conditions. Participants were told by the experimenter that she would listen to what the participant was saying as the fMRI room and experimenter room are connected through an intercom system. If the participants addressed their speech to the experimenter, participants in both groups have a direct addressee. As we intended to manipulate communicative context by the presence or absence of an addressee, this may have obscured our effect. As a last factor that may have decreased the difference between communicative and non-communicative context, we consider the possibility that although the participants in the communicative context condition met each other before the experiment started and were encouraged to interact during technical set-up, they might have forgotten they were actually working together with this other participant during the experiment. However, we do not believe this is the case: although participants could not see each other during the experiment, they could indeed hear each other. Furthermore, during the break in the experiment, participants saw each other again and almost always spontaneously started talking about their performance on the task. Their conversations showed that they were aware that the percentage that was shown to them during feedback trials reflected their joint performance: before returning to their separate rooms for the second half of the experiment, participants said things like: "*this time let's go for 100% correct!*" Finally, the correlation between individual between-speaker priming effects of conversation partners indicates that speakers are indeed influenced by their conversational partner. We found that if speaker A adapts to speaker B, speaker B adapts to speaker A to a similar extent. This result indicates that priming effects are influenced by being in a communicative context: this influence does not seem to be reflected in an increase of syntactic priming magnitudes per se, but rather by the fact that speakers can be influenced by the priming effects of their interlocutors

The fact that we found a correlation between the magnitudes of syntactic priming effects of conversation partners suggests that syntactic priming should not only be studied as an individualistic phenomenon but rather that both interlocutors should be taken into account. In the non-communicative context, we see that every individual speaker has a different susceptibility to syntactic priming: some speakers show strong syntactic priming effects, whereas other speakers do not. However, the correlation between the magnitudes of syntactic priming effects of individual speakers in a conversation pair shows something which determines the syntactic priming strength above and beyond speakers' individual susceptibility to priming: the magnitude of one speaker's priming effects is influenced by the interlocutor's priming magnitude. This finding is in line with other studies that have shown a tendency for speakers to mimic certain aspects of their interlocutor's linguistic behaviour (Capella & Panalp, 1981; Giles & Powesland, 1975; Webb, 1969; 1972). The exact mechanism through which this occurs is subject to further research. Our exploratory analyses already seem to indicate that syntactic priming effects change over time, so that speakers in a communicative pair become more similar to each other. Also, the more different syntactic priming effects of individuals in a communicative pair are at the start of the experiment, the more this difference will decrease over time. However, in the exploratory analyses we reported, syntactic priming effects were compared between two sessions. In future studies, we plan to look at change over time more carefully, and define the priming effect at the start of the experiment on the basis of a separate pre-test in which the participants are not influenced by their interlocutor. These future investigations will also investigate the directionality of the adaptation process. The present analyses can only tell us that there is at least one speaker who adapts his or her syntactic priming effects to the interlocutor. In future research, we would like to investigate whether both speakers move towards each other and end up exactly in the middle between their individual priming susceptibility, or whether one speaker could be influenced more than the other. Previous research has identified several social factors that may explain why individuals are more or less primed by their conversation partner. On the one hand, specific characteristics of an addressee seem to influence a speaker's syntactic priming effects. If these characteristics are valued positively by the speaker, syntactic priming effects are stronger (Balcetis & Dale, 2005). On the other hand, there are also characteristics of the speaker that may play a role in one's susceptibility to syntactic priming: Weatherholtz et al. (2014) found that speaker's strategy to manage conflict mediates the strength of syntactic priming effects (speakers who compromise during conflict repeat syntax more often than speakers who do not comprise).

We conclude that syntactic processing is subject to the top-down influence of being in a communicative context. We did not find evidence in favour of the hypothesis that the presence of a communicative context increases syntactic priming effects per se. Rather, the evidence we report here supports the hypothesis that communicative context influences priming effects in that speakers are influenced by each other. This indicates that it is informative to not only study syntactic priming from an individualistic perspective, but rather take the syntactic priming effects of both interlocutors into account.

CHAPTER 2B

Behavioural replication

& follow-up study

Abstract

In Chapter 2A, we reported a significant positive relationship between the syntactic priming magnitudes of two speakers in a communicative pair: the more speaker A is primed by speaker B, the more speaker B is primed by speaker A. Since this was a novel finding, we reasoned that it required replication and, if replicated, further exploration. Therefore, we ran a replication and follow-up experiment. The main aim of the experiment was to replicate the correlation between syntactic priming magnitudes of interlocutors in a communicative pair. Additionally, a non-social pre-test preceding the social two-participant syntactic priming experiment was added to the design to determine each participant's individual susceptibility to priming. However, we did not replicate our finding: we found no evidence of a relationship between the syntactic priming magnitudes of two speakers in a communicative pair. We discuss possible explanations and the implications of this non-replication.

2B.1. Introduction

The main aim of this study was to replicate the findings reported in chapter 2A. In this chapter, we reported a correlation between the syntactic priming magnitude of one speaker (as measured in response latencies) and the syntactic priming magnitude of their conversation partner. In the experiment below, we therefore measured between-modality syntactic priming magnitude in response latencies for two speakers in a communicative pair. Before describing the methods in more detail, we summarize the main differences between the design of the current study and the study reported in chapter 2A.

In the study described in chapter 2A, one participant performed the experiment while lying in an MRI scanner. In the current study, there was no fMRI component. An advantage associated with having two behavioural participants was that participants who interact and communicate with each other could be in the same experiment room and face each other during communication. This enhances the communicative and social aspect of the experimental set-up.

Another change with respect to the experiment reported in Chapter 2A is that in this study, we added a non-social pre-test to our experimental procedure. Both participants completed this pre-test in isolation to determine their individual susceptibility to syntactic priming, before they could be influenced by their partner's syntactic priming magnitude. With this, we aimed to explore whether and how syntactic priming magnitude changes in a social conversation context compared to a non-social individual context, due to interaction with a partner who may also be primed by you.

2B.2. Method

2B.2.1. Participants

Sixty naïve participants participated in the replication experiment (10 males, M_{age}: 22 years, SD: 2.6). Participants who had taken part in the study reported in Chapter 2A were excluded from participation in the replication experiment. Participants were always invited to do the experiment together. There were 30 participant pairs consisting of 2 naïve participants each (10 male-female, 20 female-female). One pair was excluded from analyses due to inadequate performance of one of the participants in the pre-test (less than 50% of the targets described correctly). All participants were Dutch native speakers who were not colour-blind and who had no language or speech disorders. All participants were compensated financially for their participation and gave written informed consent in accordance with the Declaration of Helsinki. The study was approved by the local Ethics Committee of the Social Sciences faculty of the Radboud University (Ethics Approval Number ECG2013-1308-120).

2B.2.2. Materials

Materials were identical to the materials used in Chapter 2A. Participants were presented with photographs: grayscale photographs for comprehension trials and color-coded versions of the photographs for the production trials. Colour coding was used to elicit specific syntactic constructions. For each of the transitive production photographs, two versions were created: one with the agent presented in green and the patient in red (eliciting an active sentence) and one with the patient presented in green and the agent in red (eliciting a passive sentence). Participants were not only presented with transitive, but also with intransitive and locative photographs. For intransitive photographs, the actor would be presented in red or green (colour not functional). Locative photographs were also colour coded as to elicit a locative state ("the ball lies on the table": location in red) or a frontal locative ("on the table lies a ball": location in green). For each participant, photographs were randomly chosen from the database with the restriction that individual photographs could not appear more than once in each list. Actions could be repeated, but were always depicted by a different pair of actors or with the same actors assigned to different thematic roles.

2B.2.3. Task & Trial Structure

Task and trial structure were identical to the experiment reported in Chapter 2A. Each trial starts with presentation of a verb (500 ms). The colour of this verb indicates whether a production (verb is green) or a comprehension (verb is grey) photograph is coming up. Whenever one of the participants sees a grey verb, the other sees a green verb and vice versa (see Figure 2B.1). After an ISI of 500-2500 ms both participants are presented with a photograph (2000 ms). For one of the participants this photograph is color-coded (production trial), and for the other the photograph is presented in grayscale (comprehension trial). For production trials participants were instructed to always name the green figure before the red figure, using the verb that was presented immediately preceding the photograph (stop light paradigm, Menenti et al., 2011). Participants' task during comprehension was to listen to the description provided by their partner and decide whether the photograph on their screen was identical to the photograph their partner described. Participants clicked the mouse for mismatches and were presented with feedback (every 40 trials) on how well they performed on the task as a pair. That is, feedback is not presented based on individual performance but on their performance as a pair: the proportion of trials on which they responded correctly as a team.

2B.2.4. Design

The replication experiment differed from the experiment reported in Chapter 2A in that we only measured between-participant priming effects (comprehension-to-production priming). In the experiment reported in Chapter 2A, we also included within-participant priming conditions (production-to-production priming). However, since the effect that we wanted to replicate concerned between-participant priming effects only, participants in the replication experiment never described two targets in a row: participants take turns describing photographs. From one participant's point of view, they were thus presented with alternating comprehension and production trials (Figure 2B.1).

Participants were presented with 360 photographs (opposed to 680 in the experiment reported in Chapter 2A). For each participant in a pair, half of the photographs were comprehension photographs and the other half were production photographs. To make the experiment as short as possible for the participants (and to keep the experiment as similar as possible to the experiment reported in Chapter 2A), we opted to make use of a running priming paradigm, where each production target for participant A functions as a comprehension prime for participant B and the other way around (see Figure 2B.1).

From the perspective of one participant, every production photograph was always preceded by a comprehension photograph. By color-coding production photographs, we manipulated whether they would be described with the same syntactic structure as participants had heard during the immediately preceding comprehension item or not. The factors Target Structure (Active/Passive) and Syntactic Repetition (yes/no) were crossed, so that for each participant, every production item was assigned to one out of four conditions: 1) Repeated Syntax - Active Target (active production target preceded by an active comprehension prime), 2) Repeated Syntax - Passive Target (passive target preceded by a passive prime), 3) Novel Syntax - Active Target (active target preceded by a passive prime) and 4) Novel Syntax - Passive Target (passive target preceded by an active prime). In the experiment reported in Chapter 2A, there were 4 more conditions, since we orthogonally manipulated whether the prime was presented in the same modality as the target (production-production priming and comprehension-production priming). In the current experiment, there is only comprehension-production priming possible since participants take turns describing the photographs.

For each participant, there were 20 production targets in each of the 4 conditions (80 production targets in total). These production targets are divided over 40 target blocks, where they are alternated with comprehension primes (production targets for the participant's partner). Target blocks vary in length (3-7 items, mean 5 items). Due to the fact that participants prime each other, the first item of every target block is always a prime-only item. Target blocks were alternated with filler blocks. There were 160 filler items in total. These are distributed over 40 filler blocks, in which production fillers are alternated with comprehension fillers. Filler blocks also vary in length (2 - 7 items, mean 4 items). For 25% of the filler trials we showed participants a different photograph (mismatch). Half of these fillers elicited a transitive description from the describer and half elicited an intransitive/locative sentence.

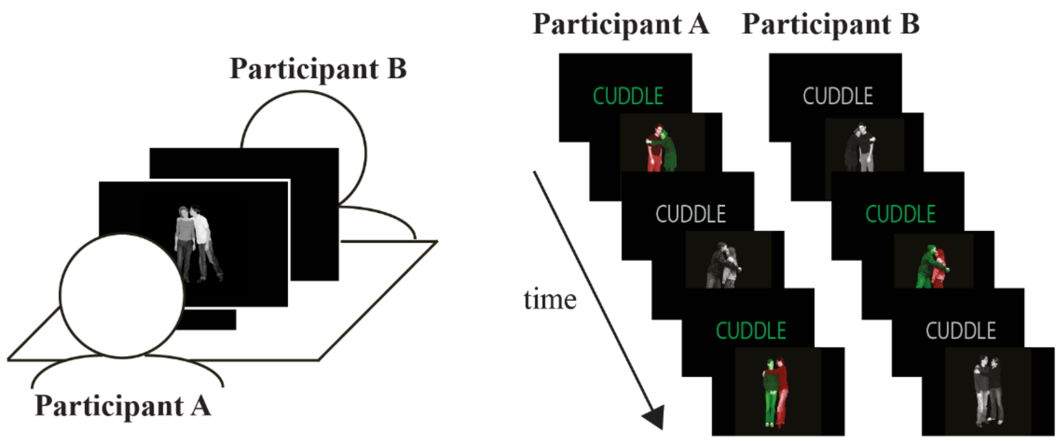

Figure 2B.1. Set up and Design. Left: Two naive participants face each other during the experiment. Right: Participants take turns describing photographs. Whenever one participant sees a production photograph, the other sees a comprehension photograph and vice versa. Production and comprehension trials are indicated by the colour of the immediately preceding verb (green is production, grey is comprehension). Participants are instructed to use this verb in their description of the photograph and to describe the green figure before the red figure. During comprehension trials, photographs are presented in grayscale.

2B.2.5. Non-social pre-test

In this replication study, we added a non-social pre-test to the experimental procedure. The goal of the pre-test was to measure each participant's individual susceptibility to syntactic priming effects, before they would be influenced by their partner. To allow for maximal comparability between pre-test and main experiment, the experiments were kept as similar as possible. The crucial difference between the non-social pre-test and the main experiment is that in the pre-test, participants were placed in an individual soundproof experiment booth, describing photographs without an addressee during production trials and listening to pre-recorded sentences during comprehension trials.

Participants were each presented with 100 photographs; 50 were comprehension photographs and 50 were production photographs. There were 32 target blocks, each consisting of a transitive comprehension prime (accompanied by a pre-recorded description in a female voice, see Menenti et al. (2011) for details) followed by a transitive production target. There were 8 production targets in each of the 4 conditions described above. There was no verb repetition between prime and target and across all 64 transitive items no verb was repeated more than twice. There were 18 filler blocks, each also consisting of a comprehension item followed by a production item. Production fillers elicited intransitive or locative sentences. There were 12 comprehension fillers for which a matching description was played to the participant (all intransitive/locative sentences), and 6 for which there was a mismatch between photograph and description (3 transitive items and 3 intransitive/locative items). Participants were instructed to press a button for mismatch trials. Every 20-30 trials (never in a target block), they were presented with a feedback screen which reflected how well they were performing on the comprehension task (the percentage of comprehension trials they had responded to correctly, i.e. button press when mismatch and no button press when no mismatch). To make sure that participants would feel like they could still improve on the task when they would work together with the other participant, we subtracted 4-6% of the percentage for each feedback moment.

2B.2.6. Procedure

We always invited two participants at the same time. Identical to the experiment reported in Chapter 2A, participants had never met before the experiment. They were picked up from the waiting room together so as to avoid any suspicion about the naivety of one participant's partner. Participants knew they would first do an individual experiment, followed by an experiment where they would work together. Participants then read the instructions for the non-social pre-test and signed informed consent forms. After being given the opportunity to ask questions, they each entered a separate soundproof booth. During the pre-test, participants were seated in front of a computer screen on which the photographs were presented. Stimuli were presented using *Presentation* software (Neurobehavioral Systems). Participants' utterances and speech onset times were recorded with a microphone and a button box was provided so that they could press a button if the photograph they saw did not match the description they heard. Participants practiced the task.

When the experimenter had made sure that both participants had no further questions, she started the experiment and coded their utterances online for correctness.

After participants completed this part of the experiment, the experimenter and participants moved to a different room. Interaction between participants was encouraged (although not in relation to the goal of the experiment). Both participants read the instructions for the main experiment. After they had been given the opportunity to ask questions, they each sat at the opposite end of a table, both with a computer screen, a microphone and a mouse in front of them. They then performed the experiment together, with the experimenter sitting behind a screen and coding participants' utterances for correctness online. After the first half of the main experiment, participants had a break during which they had something to eat and drink and interaction was encouraged. After completion of the second half of the experiment, participants filled in a questionnaire (data not analysed for this paper) and were debriefed. In total, the experiment took about 1 hour and 45 minutes.

2B.3. Results

The results of this study were analysed using two different approaches. First, we tested whether syntactic priming magnitude was influenced by being in a social context *per se* (Analysis 1). The results of the study described in chapter 2A showed no effect of social context. Here, we replicated this analysis. To check whether participants were influenced by their partner's priming magnitude, we ran a second analysis in which we tested whether participants automatically and unconsciously adapted their syntactic priming magnitude towards their partner (Analysis 2). For clarity, the different analyses, along with their results and interpretations, are discussed in separate sections.

2B.3.1. Analysis 1: Is syntactic priming influenced by being in a social context *per se*?

Participants' reaction times (milliseconds) were analysed with a linear mixed effects model, using the lmer function of the lme4 package (Bates, Maechler, & Bolker, 2012) in R (R Core Team, 2011). Incorrect responses (actors or action not named correctly) were not analysed. Our model included a fixed intercept and fixed slope for the categorical predictor variables *Syntactic Repetition* (syntax repeated between prime and target or not), *Target Structure* (active/passive) and *Context* (pre-test/main experiment). The maximal random effects structure (Barr et al., 2013) included a random intercept for Participant and Item, and random slopes of *Syntactic Repetition*, *Target Structure* and *Context* for Participant.

Results showed significant main effects for *Syntactic Repetition* ($p < .001$), *Target Structure* ($p < .001$) and *Context* ($p < .001$). Participants were faster to produce active than passive targets (pre-test: active target: 1025.08 ms ± 24.29 ms (mean ± SE); passive target: 1160.31 ms ± 37.94 ms; main experiment: active target: 903.71 ms ± 18.76 ms; passive target: 960.01 ms ± 24.29 ms) and faster to produce sentences with repeated structure than sentences with novel structure (pre-test: no repetition: 1109.56 ms ± 34.09 ms; syntactic repetition: 1075.83 ms ± 28.32 ms; main experiment: no repetition: 948.04 ms ± 21.61 ms; syntactic repetition: 915.67 ms ± 21.00 ms). Overall, participants were faster in the main experiment (931.86 ms ± 11.35 ms) than in the pre-test (1092.69 ms ± 17.34 ms). There was no significant *Syntactic Repetition* * *Target Structure* interaction and syntactic priming magnitude did not differ between contexts. There was a significant *Target Structure* * *Context* interaction ($p < 0.05$): the decrease in speech onset latency between pre-test and main experiment was stronger for passive (200.30 ms ± 24.72 ms) than for active targets (121.37 ms ± 17.97 ms).

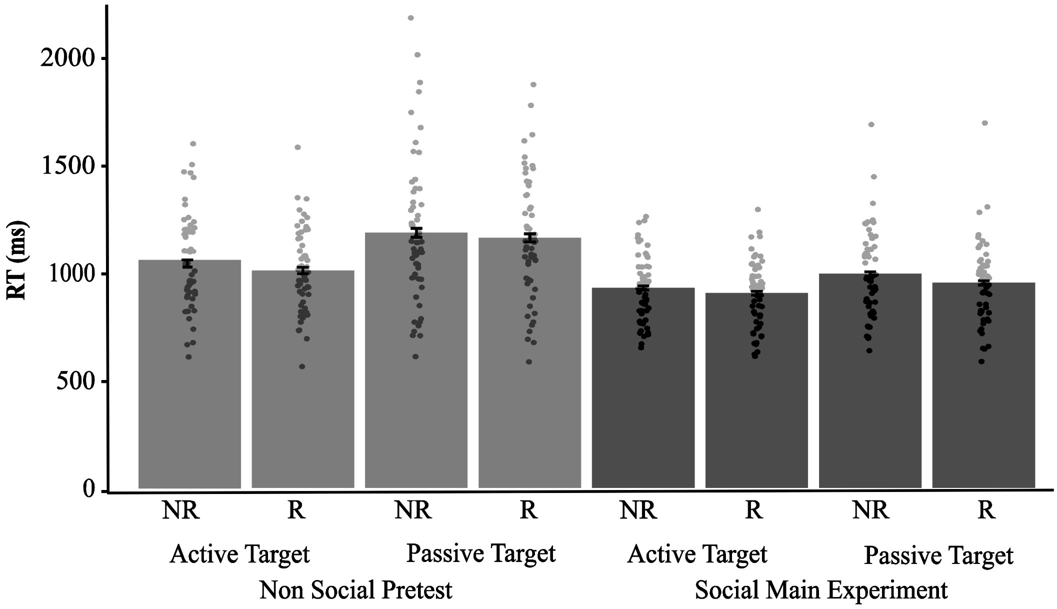

Figure 2B.2. Response time (speech onset latency) in milliseconds per condition per experimental context. For each context, participants produced targets in 4 conditions, resulting from crossing the factors *Syntactic Repetition* (NR = no repetition of syntax between prime and target, R = Repetition) and *Target Structure*. Light grey bars (left) represent the average RT per condition during the non-social pre-test. Dark grey bars (right) represent the average RT per condition during the social main experiment. Error bars represent standard error of the mean (SE). Each dot represents one participant. There were main effects of *Syntactic Repetition* (participants are faster to produce sentences with repeated syntax), *Target Structure* (participants were faster to produce active sentences) and *Context* (participants were faster in the main experiment). The effect of *Context* was stronger for passive than for active targets.

Table 2B.1. Results Linear Mixed Effects (LME) model.

	Estimate	St. Error	T value	*p*	
Intercept	1048.00	29.58	35.44	<.001	***
Syntactic Repetition	-43.44	19.34	-2.25	.025	*
Target Structure	123.61	21.27	5.812	<.001	***
Context	-132.13	23.60	-5.60	<.001	***
Syntactic Repetition * Target Structure	22.30	27.12	0.82	.411	
Syntactic Repetition * Context	19.38	22.48	0.86	.389	
Target Structure * Context	-59.18	22.64	-2.61	.009	**
Syntactic Repetition * Structure * Context	-38.63	32.04	-1.21	.228	

2B.3.2. Analysis 2: Is one speaker's syntactic priming magnitude influenced by the syntactic priming magnitude of their conversation partner?

In the second analysis, we aimed to replicate the effect reported in chapter 2A that there is a relationship between the syntactic priming magnitude of one speaker and the syntactic priming magnitude of their conversation partner. Following the method we used before, we calculated the syntactic priming magnitude for each participant (average response time in No Syntactic Repetition condition minus average response time in Syntactic Repetition condition). We removed one outlier pair from the analysis, since the syntactic priming magnitude of one of the participants was 3 SD above the group mean syntactic priming magnitude (mean: 32.37 ms, SD: 65.03 ms). Next, we ran a linear regression model with the syntactic priming magnitude of one of the participants as dependent variable and the syntactic priming magnitude of their partner as the predictor variable (N = 28 pairs). Contrary to our expectations based on the results reported in chapter 2A, we found no evidence that there is a relationship between the syntactic priming magnitudes of two participants in a communicative pair. Although there is a positive relationship, the predictor variable Priming Magnitude Participant B did not have a significant effect on Priming Magnitude Participant A (B = 0.31, SE = 0.22, $t = 1.46$, $p > 0.15$, Figure 3)

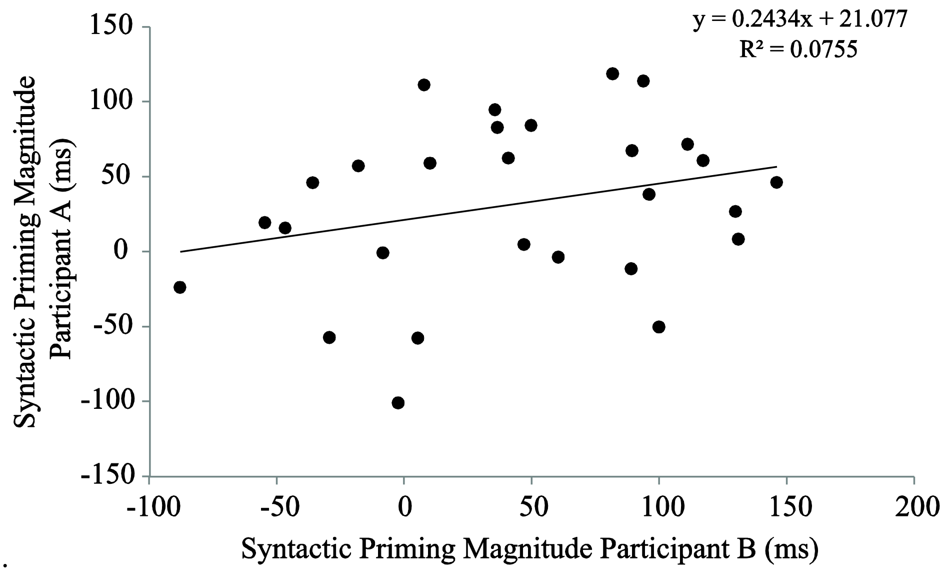

Figure 2B.3. There is a positive relationship between the syntactic priming magnitude (average response latency for targets in No Syntactic Repetition condition minus average response latency for targets in Syntactic Repetition condition) of participant A in a communicative pair and the priming magnitude of participant B in that pair. However, contrary to our expectations, this effect is not significant.

2B.4. Discussion

The present study was designed with the aim to replicate the effect we reported in chapter 2A. In that study, we reported that the magnitude of the syntactic priming effect (reflected in response latencies) of one speaker in a communicative pair was influenced by the syntactic priming magnitude of their conversation partner.

In the current study, participants completed a forced choice syntactic priming experiment with another naive participant, who was sitting across from them at the other side of the table. For both participants, we measured their response latencies when producing target sentences in the active or passive voice, in conditions where they were repeating or not repeating the syntactic structure of their partner. In line with previous results (Segaert et al., 2011, 2016) we found that speech onset latencies overall were longer for passive compared to active sentences. We also found that speech onset latencies decreased the more exposed participants were to the task environment (main effect of factor *Context*). However, the effect of *Context* was stronger for passive than for active targets. This reflects that participants implicitly learn to expect passives to appear more in the experimental environment than in their day-to-day lives: they adapt their expectations to match the statistics of their environment (Jaeger & Snider, 2013). The effect of implicit learning is stronger for passives than for actives since active sentences are much more frequent than passives in the Dutch language: experiment exposure does not change this bias since there is still a 50% distribution of passive and actives in the experiment.

As expected based on the literature on syntactic priming effects in response latencies, our results showed that speakers were faster to produce sentences with repeated syntactic structure, relative to sentences with novel syntactic structure (Corley & Scheepers, 2002; Segaert et al., 2011, 2014, 2016; Smith & Wheeldon, 2000; Wheeldon & Smith, 2003)

For each participant in a communicative pair, we calculated the magnitude of their syntactic priming effect (average speech onset latency on target trials with novel syntax minus average onset latency on target trials with repeated syntax), and tested the hypothesis that the magnitude of the syntactic priming effect of one speaker in a communicative pair is influenced by the syntactic priming magnitude of their conversation partner. In line with our previous findings, we found no evidence that being in a social, communicative context influences the magnitude of syntactic priming effects. However, in contrast to these findings, we did not find evidence that speakers in a communicative pair influence each other's syntactic priming magnitude. There are some possible explanations for this null result, each of which we will discuss below.

First, we have to consider the possibility that speaker's syntactic priming magnitude in speech onset latencies is not influenced by their conversation partner's priming magnitude. The result we reported in chapter 2A may have been a false positive.

Alternatively, there may have been other factors that have led to this result. Indeed, the experiment reported here was not an identical replication of the experiment reported in chapter 2A. In the previous study, participants did not see each other during the experiment. Indeed, one of the participants was lying in an

MRI scanner whereas the other was sitting in an experiment room. There was thus no face-to-face communication possible: the situation is more similar to communication via telephone or intercom. In the current study, there was no MRI component. For both participants, we only measured speech onset latencies. This allowed for a set-up in which participants were not only in the room, but were sitting across from each other, allowing for face-to-face communication. This change in experimental set-up increases the social and communicative aspect of the study, which might have affected how strongly the participants adapted to their conversation partner's priming magnitude. If adapting to your partner's priming magnitude facilitates communicative success, then one may expect that this effect is stronger in a situation where communication is more difficult, for example because there is no face-to-face interaction possible (as in chapter 2A). Face-to-face interaction may facilitate the communication process because it allows the speaker to directly check whether the listener understood the utterance or not, by looking at their facial expressions and body language.

To conclude, then, our study provides further evidence that syntactic priming affects speech onset latencies, not only within speakers (production to production priming, Segaert et al., 2011, 2014, 2016; Smith & Wheeldon, 2000; Wheeldon & Smith, 2003) but also between speakers, in a conversation context. However, we did not replicate our previous finding that the magnitude of a speaker's syntactic priming effect is influenced by the magnitude of their partner's priming effect. These results stress the importance of replication studies.

CHAPTER 3

Stronger syntactic alignment for speakers in the presence versus absence of an addressee

Adapted from: Schoot, L., Hagoort, P., & Segaert, K. (in prep). Stronger syntactic alignment for speakers in the presence versus absence of an addressee.

Abstract

In conversation, speakers are influenced by their partner's linguistic choices. Hearing one structural alternative, for example, leads to an increased chance that the speaker will repeat this structure in the subsequent utterance (syntactic alignment). In the current study, we tested whether the magnitude of syntactic alignment increases when speakers are interacting with a conversation partner, as opposed to doing the experiment alone, without having an addressee to talk to. We tested two hypotheses, both of which suggest a mediating influence of conversational characteristics on how much speakers align their syntactic choices with their partner: 1) using language with the goal to communicate (i.e. in a conversation with another person) increases syntactic alignment, and 2) how much your partner aligns their syntactic choices with you influences how much you align your syntactic choices with them. Although we found no evidence to support the second hypothesis, our results do support the first hypothesis: when speakers interact with a physically present conversation partner, they align more with that partner than when they perform the experiment alone, listening to recordings and not having an addressee during language production.

3.1. Introduction

In a conversation, interlocutors take turns speaking and listening. Speaking and listening are not isolated processes: what you hear as listener in one turn influences what you say as speaker in the next. Language comprehension can influence language production on many levels of linguistic processing, such as phonetics, semantics or syntax. In the current paper, we concentrate on the level of sentence structure or syntactic processing. More specifically, we focus on priming effects in speaker's syntactic choices (also known as syntactic alignment): the phenomenon that hearing a particular sentence structure leads to an increased probability that the speaker will re-use this structure in a subsequent utterance (e.g. Bock et al., 2007; Branigan et al., 2000).

Syntactic priming effects were first reported in a monologue context, as a tendency for speakers to repeat their own syntactic choices (syntactic persistence, Bock, 1986). Since then, a large body of evidence shows that syntactic priming does not only affect a speaker's syntactic choices in monologue (within one speaker) but also in dialogue (from speaker to speaker). Moreover priming effects in syntactic production are not only evident in syntactic choices, but also in production latencies (Corley & Scheepers, 2002; Segaert et al., 2011, 2014, 2016; Smith & Wheeldon, 2000; Wheeldon & Smith, 2003) and brain activation (e.g. Menenti, Segaert, et al., 2012; Schoot, Menenti, Hagoort, & Segaert, 2014; Segaert et al., 2012): speech onset latencies and brain activation are reduced when speakers produce sentences with repeated syntax, relative to novel syntax. Furthermore, syntactic priming effects have not only been reported for sentence production but also for sentence comprehension (Arai, van Gompel, & Scheepers, 2007; Branigan et al., 2005; Menenti et al., 2011; Noppeney & Price, 2004; Thothathiri & Snedeker, 2008; Traxler, 2008.; Traxler & Tooley, 2008; Weber & Indefrey, 2009) .

Explanations of the mechanisms driving syntactic priming effects have been provided by accounts that focus on implicit learning mechanisms (Chang et al., 2006, 2000; Jaeger & Snider, 2013), residual activation (Pickering & Branigan, 1998) or a combination of these (Reitter et al., 2011). Despite differences, most accounts trying to explain the cognitive mechanisms underlying syntactic priming effects share their focus of explaining how linguistic context, i.e. the linguistic properties of the preceding context up to and including the prime sentence, influences the strength of syntactic priming effects.

However, others have proposed that when syntactic priming effects are studied in a conversation, there may be additional factors that influence how much speakers are primed by their partner (Balcetis & Dale, 2005; Branigan et al., 2010; Coyle & Kaschak, 2012; Giles & Powesland, 1975; Weatherholtz et al., 2014). Indeed, a conversation is a social, communicative context in which the magnitude of the syntactic priming effect may be mediated by extra-linguistic factors, such as the speaker's social or communicative goals. In the current paper, we investigate a speaker's syntactic choices in a syntactic priming paradigm that is embedded in a social, conversation-like context. More specifically, we test two hypotheses, detailed below, which predict that being in a conversation context influences the magnitude of syntactic priming effects. In line with other studies investigating the influence of social context on the magnitude of syntactic priming effects, we will hereafter refer to the effect of syntactic priming as syntactic alignment: the tendency of one speaker to align their syntactic choices with the syntactic choices of their conversation partner.

3.1.1. Hypothesis I. Syntactic alignment increases when speakers use language to communicate (presence vs. absence of a conversation partner)

The first aim of this study is to test the hypothesis that syntactic alignment may be considered as a form of audience design (Bell, 1984): the speaker repeats the syntactic structure of their partner to facilitate comprehension by the listener (Branigan et al., 2010; Jaeger & Snider, 2013). Syntactic priming effects during listening indicate that listeners expect syntactic repetition (Arai, van Gompel, & Scheepers, 2007; Branigan et al., 2005; Thothathiri & Snedeker, 2008), and that language comprehension is facilitated when syntax is repeated, compared to when it is not repeated (Ferreira et al., 2012; Menenti et al., 2011; Noppeney & Price, 2004; Schoot et al., 2014; Segaert et al., 2012; Weber & Indefrey, 2009). Intuitively, then, we may hypothesize that when speakers want to communicate a message to their conversation partner, they may (unconsciously) try to facilitate their partner's comprehension process by repeating their syntactic choices back to them.

If the strength of syntactic alignment is influenced by the speaker's goal to facilitate comprehension for the listener, alignment should be stronger when speakers have an intention to communicate, relative to when they are talking without such an intention. Although some studies seem to provide evidence to support this hypothesis, none have tested it directly. Reitter et al. (2006) for example, report that participants involved in a spontaneous conversation align less with their conversation partner's syntactic choices than participants involved in task-oriented dialogue, in which interlocutors work together to solve a task as quickly and efficiently as possible. In other words, the more important it is that communication is smooth and efficient; the more speakers seem to align their syntactic structures with their partner, perhaps to facilitate comprehension for the listener and thereby facilitating communication.

In a different line of studies, Branigan and colleagues (Branigan, Pickering, Pearson, McLean, & Nass, 2003) found that speakers align their syntactic (and lexical, see Branigan, Pickering, Pearson, McLean, & Brown, 2011) choices more with an interlocutor that they believed to be a computer than an interlocutor they believed to be a human conversation partner (but only when the verb was repeated between prime and target). Branigan et al. (2010) argue that this result is due to a strategy to enhance communicative success in the computer condition, where the interlocutor benefits more from audience-targeted, adapted language use because they are less likely to understand what the participant is saying. Similar results come from a comparison between participants who believe to be interacting with a 'basic' or an 'advanced' computer (Branigan et al., 2011): the less intelligent participants believe the computer to be, the more they align their lexical choices with it. This is supposedly because participants in the 'basic' computer condition feel a stronger need to facilitate comprehension for their partner.

Although the studies described above provide suggestive evidence that speakers align their linguistic choices with their partner, at least in part to facilitate comprehension for that partner, most results concern lexical priming effects and moreover there are some findings which may not be in line with this idea (Ferreira et al., 2012). In the current study, we directly compare the degree of syntactic alignment of speakers who have an intention to communicate with their conversation partner with the priming magnitude of speakers who perform the same task, but do not speak with an intention to communicate because there is no addressee. Participants in the communicative context interact with another human who in turn has to act based on the participant's utterance (i.e. their performance depends on communicative success: successful comprehension of what the speaker says). A different group of participants does the same task but in the absence of an addressee to communicate with (i.e. there is only a recorded voice to provide prime sentences for the participant).

3.1.2. Hypothesis II: How much one speaker aligns their syntactic choices with their partner is influenced by how much their conversation partner aligns with them

In addition to our first aim to investigate whether speakers align their syntactic choices more when they have an intention to communicate a message to an addressee (versus when there is only a recording), we also have a second aim. We test whether speakers align more with their partner's syntactic choices when they interact with a partner who also adapts their syntactic choices to match the speaker's. In other words, we test whether the degree to which speakers align with their partner's syntactic choices is influenced by the degree to which their partner aligns their syntactic choices with them.

To the best of our knowledge, this hypothesis has not been tested before (but see Schoot et al., 2014, for suggestive results in syntactic priming effects in speech onset latencies). Previous studies on syntactic alignment have studied this effect from a somewhat individualistic perspective: they only test whether one speaker in a conversation context aligns their syntactic choices with their partner. Most often, the other speaker in a syntactic priming experiment is a scripted confederate who provides primes *for* the participant, but cannot be primed *by* the participant. In natural conversation, however, there are two naïve "participants". This means that speakers would not only be primed by their partner, their partner would also be primed by them. In the current study, we ask whether the degree to which a conversation partner aligns their syntactic choices with the participant affects the degree to which the participant aligns with the conversation partner.

If true, this would mean that speakers' production choices are not only affected by the general statistical properties of a syntactic structure, but also to the clustering properties of that structure. In an error-based implicit learning account of syntactic priming, Jaeger and Snider (2013) propose that speakers learn from recent and prior experience with a syntactic structure, and that this automatically influences their own syntactic structures. However, they do not take into account the local environment in which syntactic structures appear. Recent work has shown that listeners are sensitive to clustering properties of syntactic structures (Myslín & Levy, 2016). Listeners implicitly learn syntactic clustering properties in a specific environment, and adapt their expectations to converge on these properties.

Here, we extend this line of research by investigating whether speakers' syntactic choices are affected by the clustering properties of a syntactic structure. In other words, whether speakers' own syntactic choices are affected by the syntactic alignment magnitude of their partner. We predict that speaker A implicitly learns about the extent to which speaker B aligns their syntactic choices with them, and that this will affect speaker A's own syntactic choices, reflected in the degree to which they align with speaker B.

3.1.3. The present study

In the experiments described below, we measure the effect of syntactic priming on participants' syntactic choices (syntactic alignment). Participants describe and listen to descriptions of photographs. Target photographs can all be described with a sentence in the active (e.g. the man cuddles the woman) or passive voice (e.g. the woman is cuddled by the man). We analyse participants' syntactic choices for target trials and compare targets that follow active and passive comprehension primes with targets that follow baseline comprehension primes (a sentence with an intransitive verb, e.g. the boy runs). Based on previous literature, we expect to see a syntactic priming effect for passive primes: we predict that participants will produce more passive targets after a passive comprehension prime than after a baseline prime.

We additionally test two predictions that follow from the hypotheses presented above. Both hypotheses suggest a mediating influence of a particular characteristic of being in a conversation on how much speakers align their syntactic choices with their partner. First, we test whether the degree of syntactic alignment may be influenced by the speaker having the intention to communicate with the partner they are talking to, compared to the absence of an addressee. To that end, we compare syntactic alignment for participants in a communicative context with participants in a non-communicative context (see section 2.6 for more details). The participants in the communicative context interact with a physically present conversation partner (a confederate). The confederate describes photographs during the participants' comprehension trials and functions as an addressee during the participants' production trials. Participants in the non-communicative context listen to recorded descriptions during the participants' comprehension trials and there is no addressee during the participants' production trials. We predict stronger syntactic alignment in the communicative than in the non-communicative context. This would confirm the hypothesis that speakers align more in the presence versus absence of an addressee.

We orthogonally manipulated how much the partner who participants were paired with aligned their syntactic choices with the participant. Half of the participants in the communicative and in the non-communicative context were paired with a 'partner' (i.e. an actual conversation partner in the communicative context and a recording in the non-communicative context) who would repeat their syntactic choices back to them (adaptive partner) and the other half was presented with a partner who would not align with the participant (non-adaptive partner) (see section 3.2.5.3 for more details). If we find stronger syntactic alignment for participants who were paired with an adaptive partner than participants who were paired with a non-adaptive partner, this would confirm that one's syntactic alignment magnitude is adjusted to the alignment strength of their conversation partner.

3.2. Method

3.2.1. Participants

All participants were Dutch native speakers who were not colour-blind and had no language or speech disorders. All participants were compensated financially for their participation and gave written informed consent in accordance with the declaration of Helsinki. The study was approved by the local Ethics Committee of the Social Sciences faculty of the Radboud University (Ethics Approval Number ECG2013-1308-120).

Communicative context: Sixty-nine participants did the experiment in the communicative context. Nine participants were excluded from analyses. One of them did not believe the confederate was a naïve participant and another described all photographs with the same strategy to name the left figure first. The remaining seven participants did not produce any passive descriptions after intransitive primes, which prevented us from manipulating the confederate's "priming magnitude". Half of the 60 included participants were paired with an adaptive partner (N=30, 10 male, M_{age}: 21.1 years, SD_{age}: 2.96) and half with a non-adaptive partner (N=30, 10 male, M_{age}: 20.9 years, SD_{age}: 2.55). The partner was always the same female confederate.

Non-communicative context: Sixty participants participated in the non-communicative version of this experiment. For these participants, comprehension primes were not described by a physically present partner but previously recorded and presented to the participant via headphones. Four participants were excluded from the analysis. One participant did not complete the experiment due to sickness; two did not produce any passive descriptions after intransitive primes. The last participant was excluded because in all prime conditions, passive target production was more than 3 SD above the group mean. Twenty-nine participants were 'paired' with an adaptive computer (8 Male, M_{age}: 22.4 years, SD_{age}: 2.74), and 27 participants were 'paired' with a non-adaptive computer (5 male, M_{age}: 21.06 years, SD_{age}: 2.26).

3.2.2. Materials

All participants were presented with photographs. The content of these photographs has been described extensively elsewhere (e.g. Segaert, Menenti, Weber, & Hagoort, 2011) but briefly: there were transitive, intransitive and locative photographs. Transitive photographs depicted two actors performing a transitive action (e.g. kissing, serving). In total, there were 36 transitive actions depicted. Actor pairs either consisted of two adults or two children, and there was always one male and one female actor in the photograph. There were photographs of two pairs of children and two pairs of adults for each depicted action, each once with the female as agent and once with the male as agent. Since these photographs elicit sentences in the active or passive voice (e.g. "the man kisses the woman" or "the boy is strangled by the girl"), they were presented during target and transitive prime trials. To create a baseline prime condition, participants were presented with intransitive photographs. These photographs depicted one actor performing an intransitive action (e.g. walking). Together with locative photographs, intransitive photographs also served to elicit filler sentences. Locative photographs depicted two objects and could be described with a locative state sentence (e.g. "the keys lie on the table") or a frontal locative (e.g. "on the table lie the keys").

For each photograph, descriptions were recorded by a female Dutch native speaker (all descriptions were in Dutch). For transitive photographs, there was one recording of a description in the active voice and one in the passive voice. These recordings were presented during comprehension prime trials in the non-communicative context (in the communicative context, prime trials were described by the confederate). There were also recordings for intransitive and locative photographs, which were presented during intransitive prime trials and comprehension filler trials.

3.2.3. Trial Structure

In the communicative as well as the non-communicative context, participants were presented with alternating comprehension and production trials (Figure 3.1). Each trial (comprehension or production) started with a blank screen for 0-1000 ms, after which the verb was presented for 500 ms. The colour of this verb indicated whether a production (verb is green) or a comprehension (verb is grey) photograph was coming up. After an interval of 500-2500 ms (in which a blank screen was presented) participants were presented with a photograph (on screen for 2000 ms). For comprehension trials in the non-communicative context, a recorded description of the photograph was played to the participant. The recording started 0-1000 ms after the picture appeared on the screen. A blank screen was then presented for 1000 - 4000 ms before the next trial started (7 seconds total trial time).

3.2.4. Task

Participants' task during production trials was to describe the photograph with a concise sentence, using the verb that was presented immediately preceding the photograph. Participants were instructed to start their description as soon as possible from the moment the photograph appeared on the screen. During comprehension trials, participants listened to the description (provided by the confederate in the communicative context, a recording in the non-communicative context) and decided whether the photograph on their screen matched the description that they heard. If there was a mismatch between photograph and description, participants were instructed to press the left mouse button, after which they heard a beep.

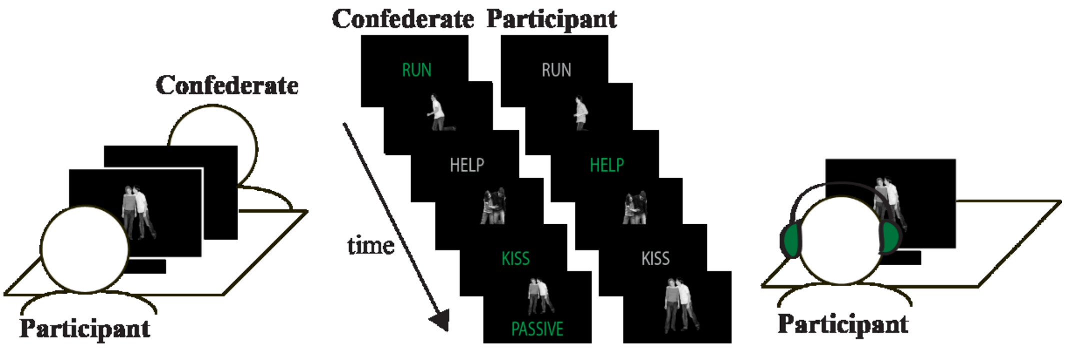

Figure 3.1. Experimental set up and trial structure. **Left**: In the communicative context, confederate and participant face each other during the experiment. They describe the presented photographs to each other. **Middle:** Participants were always presented with alternating comprehension and production trials. For the communicative context, this means that participant and confederate take turns describing photographs. Whenever the participant sees a production photograph, the confederate sees a comprehension photograph and *vice versa*. Production and comprehension trials are indicated by the colour of the immediately preceding verb (green is production, grey is comprehension). Participants are instructed to use this verb in their description of the photograph. Participants do not get instructions to produce active or passive sentences (free choice paradigm), and thus only see grayscale photographs on all trials. **Right:** In the non-communicative context, participants do the experiment alone. During comprehension trials, they listen to recorded descriptions of the presented photographs via headphones.

3.2.5. Design

3.2.5.1. Within subject syntactic priming manipulation

Each participant described half of the photographs themselves (production trials) and for the other half, they heard a description (comprehension trials), either provided by the confederate (communicative context) or by a recording (non-communicative context).

There were 100 production trials for which the participants described transitive target photographs (*participant targets*). For these, the participant was free to describe the photograph with a sentence in the active or in the passive voice. These target trials were always preceded by a prime (i.e. comprehension) trial: there were 50 transitive primes, (25 were *active primes* and 25 were *passive primes*), and 50 *baseline primes* (these were intransitive descriptions).

Participant targets that followed a baseline prime (i.e. 50 targets) were in turn followed by another transitive item (*manipulation trial*). On these items, we manipulated whether the sentence structure that the participant heard was repeated or not with respect to the target structure that was used (adaptive vs. non-adaptive partner/computer - see section 3.2.5.3 below).

Prime-target pairs were always preceded by one or more filler items. Each participant saw 170 filler photographs (115 intransitive, e.g. *the man runs*; 35 locative, e.g. *the ball is on the table;* 20 transitive). 20% of the filler items were catch items, for which the photograph participants saw did not match the description they heard. Participants were instructed to press a button when there was a mismatch between photograph and description. Every 40 trials, participants were presented with a feedback screen with the percentage of trials to which they had responded correctly: through a button press when there was a mismatch and no button press when there was no mismatch.

This resulted in 420 photographs per experimental list: 100 photographs accompanied by prime descriptions, 100 target photographs, 50 photographs for the manipulation trials and 170 filler photographs.

The order of filler, prime and target trials was randomized for each participant, with the restriction that targets were always preceded by a prime and intransitive prime-target blocks were always followed by a manipulation trial. Furthermore, for each prime structure (active or passive), half of the items were presented in the first part of the experiment and the other half in the second part of the experiment (separated by a break). For each participant, photographs were randomly chosen from the database with the restriction that individual photographs could not appear more than once in each list. Actions could be repeated within a list, but only when depicted by different actors or with the same actors assigned to different thematic roles.

3.2.5.2. Between-subject manipulation: communicative vs. non-communicative context

The crucial difference between communicative and non-communicative context was that in the communicative context, participants interacted with a confederate, whom they believed to be another naive participant (this was checked after the experiment: participants who indicated they thought they were interacting with a confederate were removed from further analysis). Participants described the pictures to the confederate during production trials, and listened to the confederate's descriptions of the photographs during comprehension trials. In the non-communicative context, participants did not talk to anyone during production trials and during comprehension trials the photographs were accompanied by a pre-recorded description.

To further increase the contrast between the communicative and non-communicative context, participants got feedback on their performance on the mismatch detection task. In the non-communicative context, the score was based merely on the participant's individual performance during comprehension trials. In the communicative context, however, we stressed that 'participants' (participant and confederate) should work together to increase their score. The performance score thus reflected a team effort: pairs could only achieve a good performance if they described the pictures correctly to their partner as well as paid attention to what their partner was saying. Indeed, as an additional measure to avoid suspicion about the naivety of the confederate, the confederate was also instructed to detect mismatches. In the communicative context, we created mismatches by presenting different photographs to confederate and participant. Half of the mismatches had to be detected by the participant (participant comprehension trials) and half by the confederate (participant production trials).

We ensured an identical degree of experimental control in the communicative and the non-communicative contexts by manipulating the behaviour of the confederate. The confederate and the participant were sitting opposite each other, both facing a computer screen (see Figure 3.1). On the confederate's computer screen, transitive photographs were always accompanied with the word "active" or "passive" (pre-programmed). The confederate was instructed to describe the photograph with an active or a passive sentence respectively, using the verb presented immediately preceding the photograph. Crucially the participant was led to believe that the confederate was also freely describing the photographs.

3.2.5.3. Between subject manipulation: adaptive vs. non-adaptive partner/computer

Fifty *manipulation trials* were included to test whether participants' priming magnitude is affected by their partner's priming magnitude. Do participants repeat their partner's syntactic choices more when their partner repeats their syntactic choices more?

Like 'standard' comprehension prime trials, manipulation trials were all transitive photographs accompanied by a description in the active/passive voice. Different from the comprehension primes though, sentence structure varied depending on the structure that was used by the participant in the preceding target. The aim was to create two conditions. In the first condition, the participant's marked syntactic choice (i.e. passive sentence production after a baseline prime) would consistently (in 90% of the cases) be repeated back to them in the next trial. This would reflect a situation in which the partner/computer is strongly primed by the participant. In other words, the partner/computer adapts their syntactic choices to match the participant's syntactic choices. In the communicative context, we call this condition the *Adaptive Partner* (AP) condition. An identical condition was created in the non-communicative context: the *Adaptive Computer* (AC) condition. We compared these conditions with the *Non-Adaptive Partner* (NAP) and the *Non-Adaptive Computer* (NAC) conditions: in the latter condition, in 90% of the cases, the participant's marked syntactic choices would rarely be repeated in the following manipulation trial (only in 10% of the cases). The crucial manipulation between adaptive and non-adaptive conditions was thus after a participant produced a passive target following a baseline prime: in the adaptive conditions, the passive would be repeated in 90% of the cases and in the non-adaptive condition, the passive target structure would only be repeated in 10% of the cases. For active targets produced by the participant, there was no difference between the two conditions: actives were always repeated for 90% of the cases.

Since passives are often repeated in AP and AC, but not in NAP and NAC, we had to make sure that any difference between conditions is not due to participants hearing more passives overall when they were assigned to an adaptive condition. Therefore, on average 7.5 (i.e. the average number of passive manipulation trials in AP) additional transitive fillers were described with a passive in the NAC and NAP conditions, whereas these items are all described with an active sentence in the AC and AP conditions. Thus, importantly, there was no between-group difference in the total number of passives participants heard between adaptive and non-adaptive conditions. The only difference was whether these passive sentences were produced because the confederate or computer was 'primed' by them or not.

	Adaptive	Non-Adaptive
Communicative	**Adaptive Partner** Priming experiment with confederate who repeats participant's syntactic choices 90% of the time	**Non-Adaptive Partner** Priming experiment with confederate who repeats participant's syntactic choices 10% of the time
Non-Communicative	**Adaptive Computer** Priming experiment with computer who repeats participant's syntactic choices 90% of the time	**Non-Adaptive Computer** Priming experiment with computer who repeats participant's syntactic choices 10% of the time

Figure 3.2. Summary of the between-subject manipulations: we orthogonally manipulated the factors Communicative Context (participants are interacting with a confederate in the communicative context versus listening to a recording) and Partner Type (the participant's syntactic choices are repeated in 90% of the time in the adaptive partner/computer condition versus 10% of the time in the non-adaptive partner/computer condition).

3.2.6. Pre-experiment training session

Since the adaptive/non-adaptive between-subject manipulation hinges on participants producing passive target descriptions after intransitive primes, we added a training session to the experimental procedure. Previous studies have shown that such a training session increases the chance that participants produce passive targets in the main experiment (Kaschak, Loney, & Borreggine, 2006; Segaert et al., 2011).

To allow for maximal passive production in the main experiment, training and the main experiment were kept as similar as possible. In the training session, participants were presented with 120 photographs. In the communicative context, half of them were described by the participants and the other half by the confederate. In the non-communicative context, participants did the training session together with another participant, after which they would both proceed to participate in the main experiment individually. We opted for this option to ensure that any differences between participants in the communicative and non-communicative context would not be due to a difference in the training session: e.g. because a training session with a partner is more effective than a training session in which participants listen to recordings in the comprehension primes. Any difference between the two groups is thus due to having a physically present communicative partner or not during the main experiment.

In the training session, all photographs depicted two actors performing a transitive action. Comprehension photographs were shown in grayscale. The participant's task was to passively listen to the description that was provided by the other participant. Different from the main experiment, in the training session, production photographs were color-coded; one of the figures was coloured red and the other was presented in green. Participants were instructed to always name the green figure before the red figure, using the verb that was presented immediately preceding the photograph (stop light paradigm, Menenti et al., 2011). For 90% of the transitive photographs, the patient was coloured green and the agent red. This resulted in a passive sentence for 90% of the trials (e.g. "The woman is hugged by the man"). For the other 10% of the trials, the agent was green and the patient was red, resulting in an active sentence (e.g. "The man hugs the woman"). Each participant saw a unique list of photographs and no participant saw one photograph more than once. The order in which passive and active trials were presented was randomized for each participant, with the restriction that there was maximally one active target in each 10 targets.

3.2.7. Procedure

In all contexts, participants were told that they were invited to do two experiments, at least one (two in the communicative context) together with another participant. In the communicative context, participant and confederate were picked up from the waiting room together so as to avoid any suspicion about the naivety of the confederate. In the non-communicative context, participants were also picked up from the waiting room together.

The procedure was largely identical for the training session and the main experiment. Participant(s) and confederate read the instructions for the respective experiment and signed informed consent forms (only once, after reading instructions for the training session). After being given the opportunity to ask questions, in the communicative context, participant and confederate each sat in front of a computer screen, facing each other (Figure 3.1, left panel). They had a microphone in front of them and a mouse to identify mismatches in the main experiment. In the non-communicative context, participants could hear each other in the training session, but carried out the main experiment in a soundproof booth (at the same time as the second participant, but individually). They were also in front of a computer screen, with a microphone and a mouse, and were additionally wearing headphones through which recordings were played to them in the main experiment (Figure 3.1, right panel).

The participant and confederate (communicative context), or the two participants (non-communicative context) practiced the task together (only for the training session). When the experimenter had made sure that participants understood the task and had no further questions, the respective experiment was started. During the experiment, the experimenter was not visible to the participants. She coded the utterances online for correctness. An utterance was incorrect if participants did not use the presented verb in their description or when agent and/or patient were not named correctly (e.g. participants said “woman” when a girl was shown). After the first half of the main experiment, there was a break during which participant(s) and confederate got something to eat and drink and interaction was encouraged. After completion of the main experiment, we checked whether the participant believed the other participant/confederate was also a naive participant.

If not, this participant would be excluded. Additionally, participants filled in two questionnaires (for more information see Supplementary Materials). The training session took about 11 minutes; the main experiment took about 50 minutes. The total session (including reading the instructions, the break and filling in the questionnaires) took about 1 hour and 45 minutes.

3.2.8. Data analysis approach

Participants' syntactic choices were analysed with a generalized linear mixed effect model, using the glmer function of the lme4 package (Bates, Maechler, & Bolker, 2012) in R (R Core Team, 2011). Target responses were coded as 0 for actives and 1 for passives. Incorrect responses (actors or action not named correctly) were not analysed.

Our model included fixed effects for the categorical predictor variables *Prime Structure* (active / passive / intransitive), *Communicative Context* (communicative / non-communicative) and *Partner Type* (adaptive/ non-adaptive), two-way interactions *Communicative Context* * *Prime Structure* and *Partner Type* * *Prime Structure*, and three-way interaction *Communicative Context* * *Partner Type* * *Prime Structure*. The factor *Prime Structure* was dummy-coded (all means compared to reference group: intransitive primes). For the other two categorical factors we used sum-contrasts. Random intercepts were included for participants and items, and random by-item slopes for *Communicative Context* and *Partner Type* (this is the maximal random effects structure for which convergence was reached; Barr, Levy, Scheepers, & Tily, 2013).

3.3. Results

We excluded 0.9% (106 out of 11599) of target responses because they were not described correctly (see section 3.2.7: Procedure).

There was a main effect of *Passive Prime Structures* on the production of passive targets ($p < .001$, Table 3.1): across all participant groups, participants used more passive sentences to describe target photographs after they had heard a passive prime sentence, relative to the baseline (intransitive prime). Consistent with the inverse preference effect reported frequently in the literature, there was no syntactic priming effect for actives: participants did not produce more active sentences after an active prime than after a baseline prime. See Figure 3.3 for the average percentage of passive targets after active, passive and baseline (intransitive) primes.

Although the effect of syntactic priming was present across all groups, it was stronger for participants in the communicative context than for participants in the non-communicative context, as evidenced by a significant *Communicative Context* * *Prime Structure* interaction (p < .05, Table 3.1). This interaction is visualized in Figure 3.4. We found no evidence in favour of the hypothesis that interacting with an adaptive partner increases a speaker's own priming magnitude (relative to a non-adaptive partner): interactions *Partner Type* * *Prime Structure* or *Communicative Context* * *Partner Type* * *Prime Structure* were not significant.

Table 3.1. Results general linear mixed effects model.

	Coefficient	SE	Wald *Z*	*p*
Intercept	-1.85	0.11	-17.48	<.001 ***
Active Prime	-0.09	0.06	-1.36	.175
Passive Prime	0.56	0.06	9.34	<.001 ***
Communicative Context	-0.14	0.09	-1.61	.108
Adaptive Partner Type	-0.08	0.08	-0.92	.359
Active Prime * Communicative Context	0.06	0.07	-0.86	.390
Passive Prime * Communicative Context	0.13	0.06	2.22	.026 *
Active Prime * Adaptive Partner Type	-0.05	0.07	-0.73	.461
Passive Prime * Adaptive Partner Type	0.01	0.06	-0.15	.883
Communicative Context * Adaptive Partner Type	0.06	0.08	0.70	.482
Active Prime * Communicative Context * Adaptive Partner Type	-0.06	0.06	-0.92	.360
Passive Prime * Communicative Context * Adaptive Partner Type	0.00	0.06	0.02	.986

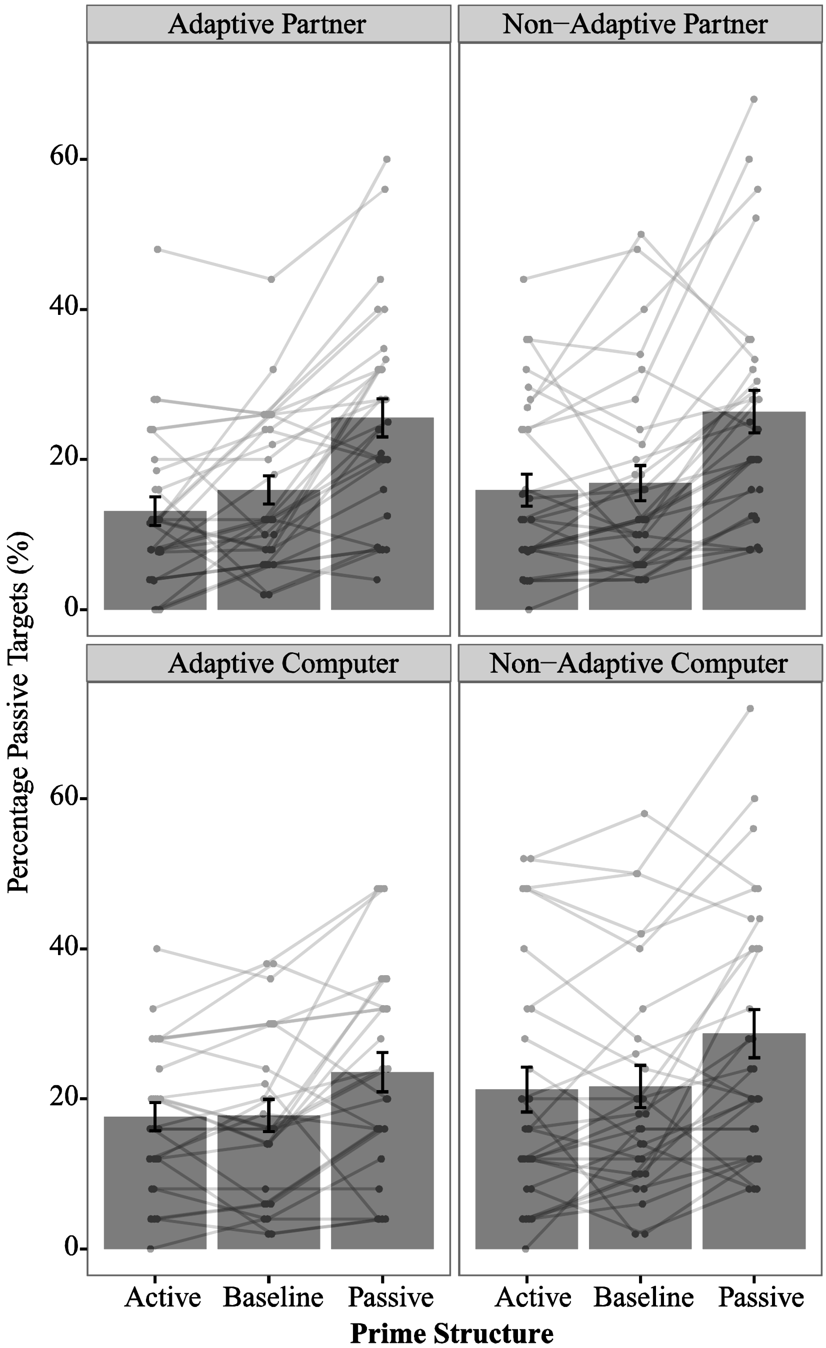

Figure 3.3. Percentage passive targets per participant group, per prime structure. Bars represent group mean per prime structure, error bars represent standard error of the mean (SE). Each dot represents one participant; connected dots are data points from the same participant. There was an effect of passives primes on syntactic choices overall, which was stronger for the communicative compared to the non-communicative condition. We found no evidence for a difference between adaptive and non-adaptive conditions.

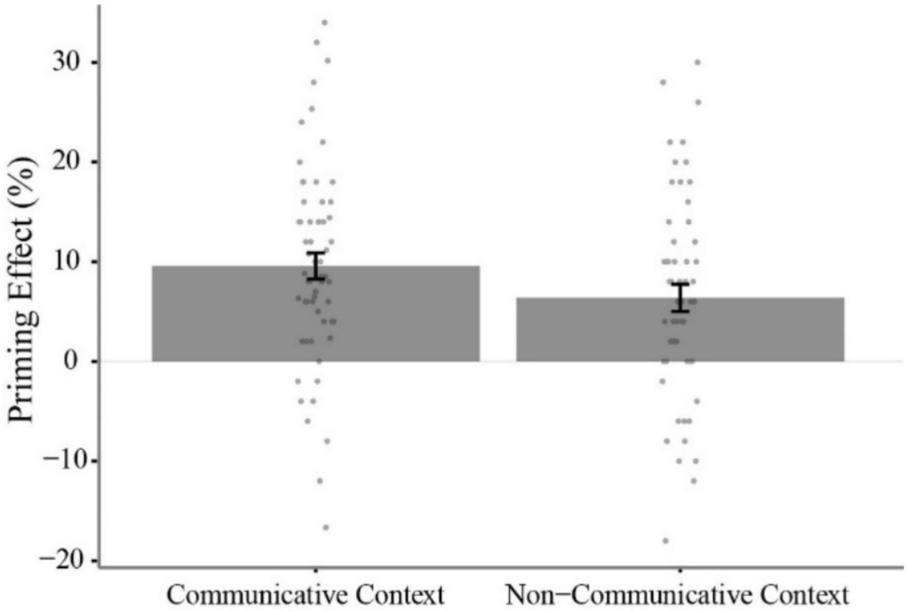

Figure 3.4. There was a stronger priming effect (% passive targets after a passive prime minus % passive targets after a baseline prime) in the communicative context (left) compared to the non-communicative context (right). Bars represent group mean per prime structure, error bars represent standard error of the mean (SE). Each dot represents one participant.

3.4. Discussion

In the present study, we measured the effect of syntactic priming on participants' syntactic choices. Participants described and listened to descriptions of photographs. Target photographs were all described with a sentence in the active (e.g. the man cuddles the woman) or passive voice (e.g. the woman is cuddled by the man). We analysed participant's syntactic choices for target trials and compared targets that followed active and passive comprehension primes with targets that followed baseline comprehension primes (a sentence with an intransitive verb, e.g. “the boy runs”).

We additionally tested two hypotheses that suggest a mediating influence of being in a conversation on the magnitude of speakers' syntactic priming effects. First, we tested whether syntactic priming magnitude is influenced by the speaker's intention to communicate with the partner they are talking to. To that end, we compared the magnitude of syntactic priming effects for participants in a communicative context with participants in a non-communicative context. We orthogonally manipulated the 'syntactic priming magnitude' of the partner participants were paired with. Half of the participants in the communicative and in the non-communicative context were paired with a 'partner' (i.e. an actual conversation partner in the communicative context and a recording in the non-communicative context) who repeated their syntactic choices back to them and the other half was presented with a partner who was not 'primed' by the participant.

3.4.1. Syntactic priming and the inverse preference effect

We replicated previous studies that have reported syntactic priming effects for passive/active alternations (Bock, 1986; Bock & Griffin, 2000; Hartsuiker & Kolk, 1998; Segaert et al., 2011). As expected based on this literature, our results showed significant syntactic priming effects for passives, but not for actives. That is, participants produce significantly more passive sentence descriptions for target pictures following a passive prime sentence than for target pictures following a baseline prime, whereas they did not produce more active sentences after an active prime than after a baseline prime. In other words, there is an inverse preference effect: priming effects on syntactic choices are stronger for the less preferred alternative (Bernolet, Hartsuiker, & Pickering, 2009; Bock, 1986; Bock & Loebell, 1990; Hartsuiker & Kolk, 1998; Segaert et al., 2011).

3.4.2. Syntactic alignment increases when speakers use language to communicate with their conversation partner

Our results support the hypothesis that participants in the communicative context would show stronger syntactic priming effects than participants in the non-communicative context. Participants in these two contexts performed exactly the same task: they described photographs and listened to descriptions of photographs. Across conditions, the number and distribution of primes and targets was identical. If syntactic alignment is a purely low level, automatic effect of priming particular aspects in a linguistic utterance (here: sentence structure) on subsequent language production, we should not have found a difference between these two groups. However, we did find a difference between the two groups, indicating that syntactic alignment is influenced by higher order, social or communicative goals that are associated with having a real conversation partner.

The only difference between the two groups is that participants in the communicative context listened to descriptions of a physically present partner, and described photographs to that partner. The partner then had to make a decision based on the description of the participant: are the photographs the same or not? In the non-communicative context, participants listened to recorded descriptions. Crucially, when they described the photographs themselves, there was no addressee: contrary to the communicative context, in the non-communicative context, participants were thus describing without anyone having to understand and act on their descriptions. In the non-communicative context, there is no need to facilitate comprehension for the listener because there is no listener. Therefore, we argue that the reason why we find a difference in syntactic priming magnitude of participants in the communicative and the non-communicative context is because in the communicative context, participants want to facilitate language processing for their partner, and alignment facilitates language comprehension (see also Branigan et al., 2010; Jaeger & Snider, 2013; Reitter, Moore, & Keller, 2010).

However, there is one caveat to our explanation. By trying to make the difference between the communicative and the non-communicative context as strong as possible, we opted for a design in which the conversation partner in the communicative context was physically present. Therefore, the communicative and non-communicative context did not merely differ in terms of having a communicative intention or not, but also in the physical presence/absence of a conversation partner. The presence of a conversation partner could have influenced syntactic alignment in ways which are not directly linked to communicative intent.

Firstly, it is possible that in the communicative context, participant and confederate aligned on lower levels of linguistic or non-linguistic behaviour, and that alignment at these lower levels percolated up to alignment at the higher sentence level (Pickering & Garrod, 2004). If the confederate and participant aligned on lower levels of linguistic processing (e.g. intonation pattern, speech rhythm), this may have led to more alignment at higher levels, and thus more syntactic alignment. In contrast, recordings could not adapt to the participant on any levels. Future studies could isolate the influence of communicative intent on syntactic alignment by comparing two groups of participants who perform a syntactic priming experiment in isolated, soundproof booths. In one group, participants would be led to believe that the recordings are actually live descriptions of another participant and that they are doing the task together. Crucially, participants should feel like they are actually communicating a message to their partner, so they should be provided with feedback about the partner's response. If there is a difference between the magnitude of syntactic alignment in this group and a second group of participants who are told they are listening to recordings (no belief manipulation), we can be sure that this difference is due to having or not having an intention to communicate with a conversation partner.

Secondly, having an actual conversation partner means that social goals come into play. It has been suggested that the (desired) relationship between speaker and listener can influence syntactic alignment (Balcetis & Dale, 2005; Coyle & Kaschak, 2012; Weatherholtz et al., 2014; but see Schoot, Heyselaar, Hagoort, & Segaert, (2016) for a contrasting account). We cannot exclude the possibility that participants in the communicative context are more strongly primed by their partner because they actually have a partner they could want to have a social relationship with, whereas this is not an option in the non-communicative context. However, if this were the case, we would have expected an effect of what the participant thought of the confederate on their syntactic priming magnitude. In a separate analysis (see Supplementary material), we tested this hypothesis using the results from the Relationship Questionnaire that participants filled in at the end of the experiment. Using Principal Component Analysis, we extracted two components from this questionnaire: one reflecting how likeable participants thought their partner was and one reflecting how shy they thought they were. However, we found no evidence that the participants' score on either of these components influenced their syntactic priming magnitude (replicating the effect reported in Schoot et al., 2016). Therefore, we do not think that the difference in syntactic alignment between communicative and non-communicative context is due to the social goals of the speaker, but is more likely to be due to effects of communicative intention.

To sum up this section: our results showed that syntactic alignment is affected by being in a social, communicative (conversation-like) context. This is evidence that syntactic alignment cannot be explained by mechanisms that are encapsulated within the language system alone (Branigan et al., 2010); accounts of syntactic alignment should also be able to explain top-down effects of being in a communicative context.

3.4.3. One speaker's syntactic priming magnitude is not influenced by their conversation partner's priming magnitude

We did not find evidence that the degree to which speakers align syntactic choices with their partner is affected by the 'syntactic priming magnitude' of their partner (irrespective of whether that partner was a physically present person or a recording). Hence, contrary to our expectations, it was not the case that speakers who were paired with a partner who was strongly primed by them (repetition of passive targets in 90% of the cases) would also be strongly primed by that partner (more so than speakers who were paired with a partner who was weakly primed by them, repetition in 10% of the cases).

Although it is possible that speakers are not influenced by the syntactic priming magnitude of their partner (contrary to what was suggested by Schoot et al., 2014), null results should be interpreted with caution. One explanation for the fact that we did not find a difference between the two groups is that our critical manipulation depended on participants 'spontaneously' producing passive descriptions of target photographs that were presented following baseline primes. Between subjects, we then manipulated whether the confederate would use a passive/a recording of a passive sentence was played (syntactic repetition) or whether an active sentence was used to describe the subsequent ‘manipulation trial’. Although we added a training phase to the experimental procedure with the goal to increase the proportion of passives produced in the main experiment, and excluded participants who had not produced any passive targets after a baseline (and were thus not exposed to the manipulation at all), there was a lot of variation between participants with respect to how many passives they produced after a baseline prime. Consequently, there was a lot of variation in how much exposure participants had to the "priming magnitude" of their 'partner' (the confederate or recording). On average, participants in the adaptive conditions only produced 8.75 passive targets (out of 50) after a baseline prime (minimum of 1 - maximum of 22, SD = 5.25). The manipulation of conversation partner's (confederate or computer) degree of alignment is thus a very subtle manipulation.

3.4.4. Conclusion

Our results suggest that there is a top-down influence of being in a conversation context, i.e. using language to communicate with a conversation partner, which increases syntactic alignment. In other words, speakers' priming effects are stronger when primes are provided by and targets are addressed to a conversation partner than when primes are pre-recorded utterances and speakers produce targets without addressing someone.

Supplementary Analysis

In an extra analysis, we tested the hypothesis that the magnitude of syntactic priming is influence by the speaker's opinions of their conversation partner. For this analysis, we only included participants in the communicative context.

After completing the experiment, every participant in the communicative context filled in a questionnaire (Relationship Questionnaire). This questionnaire was based on the questionnaire used by Weatherholtz et al. (2014) and consisted of 7 statements (Table S1). Participants indicated on a 6 point Likert scale how much they agreed with each of the statements (1: not at all, 6: completely agree). We ran a Principal Component Analysis (PCA) to reduce the number of variables in this dataset, so that we could include the merged variables as predictors in a subsequent statistical analysis of the participant's syntactic choices. PCA was run on a combined dataset with data from this study and other studies (Heyselaar, Hagoort, & Segaert, 2015; Schoot, Heyselaar, et al., 2016). After applying varimax rotation, 2 components were extracted, which we termed Likeability and Shyness. We included each participant's PCA score on these variables in a general linear mixed effects model to analyse the participant's syntactic choices on target items after different prime types. As in the analysis reported in the Results section above, Target responses were coded as 0 for actives and 1 for passives. Incorrect responses (actors or action not named correctly) were not analysed.

Table S1. Results of the Questionnaire PCA (Questions presented in Dutch). Loadings greater than 0.4 are in bold as these items contribute most to the meaning of a factor. Loadings less than 0.1 are omitted for clarity.

Relationship Questionnaire	Likeability	Shyness
I could be friends with my partner	**0.80**	
My partner is similar to me	**0.70**	-0.26
My partner appeared generous	**0.65**	0.34
My partner appeared intelligent	**0.65**	
My partner appeared selfish	-0.34	**0.54**
My partner appeared shy	-0.25	**0.72**
My partner appeared enthusiastic	**0.67**	
Proportion Explained	0.71	0.29

The final model included fixed effects for the categorical predictor variable *Partner Prime Structure* (active/passive/intransitive) and the two social evaluation components Likeability and Shyness. We furthermore included two-way interactions *Prime Structure* * Likeability and *Prime Structure* * *Shyness*. The factor *Prime Structure* was dummy-coded (all means compared to reference group: intransitive primes). Random intercepts were included for participants and items, and due to convergence issues, we did not include random by-item or by-participant slopes.

There was a main syntactic priming effect for passives (more passive targets after passive prime than after a baseline prime), but not for actives. The interactions *Prime Structure* * *Likeability* and *Prime Structure* * *Shyness* were not significant. In other words, there was no effect of the participant's social evaluation of the confederate on how much they aligned their syntactic choices with them.

CHAPTER 4

Does syntactic alignment effectively influence how speakers are perceived by their conversation partner?

Adapted from: Schoot, L., Heyselaar, E., Hagoort, P., & Segaert, K. (2016). Does Syntactic Alignment Effectively Influence How Speakers Are Perceived by Their Conversation Partner? *PloS one*, *11*(4), e0153521.

Abstract

The way we talk can influence how we are perceived by others. Whereas previous studies have started to explore the influence of social goals on syntactic alignment, in the current study, we additionally investigated whether syntactic alignment effectively influences conversation partners' perception of the speaker. To this end, we developed a novel paradigm in which we can measure the effect of social goals on the strength of syntactic alignment for one participant (primed participant), while simultaneously obtaining usable social opinions about them from their conversation partner (the evaluator). In Study 1, participants' desire to be rated favourably by their partner was manipulated by assigning pairs to a Control (i.e. primed participants did not know they were being evaluated) or Evaluation context (i.e. primed participants knew they were being evaluated). Surprisingly, results showed no significant difference in the strength with which primed participants aligned their syntactic choices with their partners' choices. In a follow-up study, we used a Directed Evaluation context (i.e. primed participants knew they were being evaluated and were explicitly instructed to make a positive impression). However, again, there was no evidence supporting the hypothesis that participants' desire to impress their partner influences syntactic alignment. With respect to the influence of syntactic alignment on perceived likeability by the evaluator, a negative relationship was reported in Study 1: the more primed participants aligned their syntactic choices with their partner, the more that partner decreased their likeability rating after the experiment. However, this effect was not replicated in the Directed Evaluation context of Study 2. In other words, our results do not support the conclusion that speakers' desire to be liked affects how much they align their syntactic choices with their partner, nor is there convincing evidence that there is a reliable relationship between syntactic alignment and perceived likeability.

4.1. Introduction

In social interaction, humans tend to imitate their partner's posture, gestures and mannerisms, without being aware that they do so (behavioural mimicry (Chartrand & Bargh, 1999). This kind of automatic imitation does not only occur in behavioural mannerisms, but also in verbal interaction. Speakers imitate low-level linguistic features such as accents (Giles & Powesland, 1975), speech rate (Webb, 1969) and speech rhythm (Cappella & Planalp, 1981), but they also repeat their conversation partner's lexical (Brennan & Clark, 1996) and syntactic choices (Branigan et al., 2000). The latter is called syntactic alignment (Pickering & Garrod, 2004). Syntactic alignment is a result of a largely automatic priming mechanism (Pickering & Garrod, 2004) and therefore often explained by mechanisms of implicit learning (e.g. Chang et al., 2006, 2000; Jaeger & Snider, 2013), residual activation (e.g. Pickering & Branigan, 1998) or a combination of both (e.g. Reitter et al., 2011). In addition, it has been proposed that syntactic alignment can function as a tool to mediate interpersonal distance (Balcetis & Dale, 2005; Coyle & Kaschak, 2012; Giles & Powesland, 1975; Lev-Ari, 2015; Weatherholtz et al., 2014). These theories suggest that the (desired) relationship between speakers in a conversation can modulate the strength of syntactic alignment. For example, speakers would show stronger syntactic alignment effects when they interact with a partner they like or want to be associated with than when they interact with a partner they do not like or want to distance themselves from (Giles & Powesland, 1975).

Some recent studies have provided initial evidence in line with the hypothesis that the strength of syntactic alignment can be influenced by the speakers' feelings toward their conversation partner. However, it is unclear whether this effect is positive or negative: different studies report different effects. Balcetis and Dale (Balcetis & Dale, 2005), for example, let participants perform a syntactic priming experiment with a same-sex confederate. Before the start of the actual experiment, participant and confederate each responded to a set of questions. The confederate's answers to the questions were scripted so that for half of the participants, the confederate would come across as nice and for the other half as mean. The results of a subsequent syntactic priming experiment show that participants align their syntactic choices more when they were paired with the 'nice' participant than when they were paired with the 'mean' participant.

Contrasting results come from a study by Weatherholtz, Campbell-Kibler and Jaeger (Weatherholtz et al., 2014). They let participants listen to one out of three different speakers, each with a different accent, talking about a political issue from a specific ideological standpoint. Results from a directly following syntactic priming experiment in which participants were primed with double object (DO) or prepositional object (PO) structure, showed that participants align *less* with PO prime sentences when they perceived themselves to be more similar to the speaker. Furthermore, participants aligned less with DO prime sentences when they perceived the speaker to be smart. Hence, in this study, there is a negative effect of personality traits of the speaker that are generally considered positive on syntactic alignment.

Although conflicting, the aforementioned studies do provide some evidence in favour of the idea that the strength of syntactic alignment can be influenced by social aspects of an interaction. One possibility why results might have been conflicting is that the focus in these studies is very unidirectional: it is only investigated whether speakers' feelings about their conversation partner influence syntactic alignment. Of course, there might be a relationship between alignment and managing interpersonal distance in the opposite direction as well (Giles & Powesland, 1975). It may not just be the likeability of your partner *per se*, but rather also how much you want your partner to like you, which influences syntactic alignment. Although generally these two will be highly correlated (likeability of your partner may lead to a reciprocal feeling of wanting to be liked by your partner), one could imagine situations where speakers want their partner to like them, irrespective of whether they like their partner or not. This is for example the case in a job interview. Applicants may not necessarily think highly of their potential employer's personality, but if they really want the job, they would want the employer to evaluate them positively anyway. Since neither Balcetis and Dale nor Weatherholtz et al. have explicitly manipulated the social goals of the primed participants, this might contribute to the conflicting results they have reported:

maybe there is a difference between studies in how much speakers want to be evaluated positively by their partner.

In the current study, we therefore test whether the social goal to make conversation partners evaluate them favourably automatically influences the strength of speakers' syntactic alignment, irrespective of how they feel about their partner. To our knowledge, there has only been one previous study with a similar research question. Coyle and Kaschak (Coyle & Kaschak, 2012) showed that when speakers have an (unconscious) goal to make their partner like them, they tend to align less with their partner's syntactic choices. The experimenters let heterosexual participants perform a syntactic priming experiment with a female confederate. The male participants show weaker syntactic alignment effects in response to a female confederate with a higher level of fertility (measured by the confederate's menstrual cycle). This difference was absent for heterosexual females talking to a female confederate. Coyle and Kaschak suggest that *not* aligning with your conversation partner's syntactic choice could be a way of displaying creative behaviour (in this case, innovative rather than repetitive syntactic choices), which could be an attractive quality in potential mates (Haselton & Miller, 2006).

The results reported by Coyle and Kaschak suggest that implicit social goals, such as speakers' desire to make their partner like them, can indeed influence the strength of syntactic alignment. If that is true, we furthermore expect that the degree with which one conversation partner aligns with the second should influence how the second conversation partner feels about the first: it should influence the first participant's perceived likeability. Therefore, in the current experiment, we do not only ask whether and how speakers adapt their syntactic alignment behaviour to match their social goals, but also whether adaptation is effective: are participants' evaluations of their conversation partners influenced by how much the partner aligns their syntactic choices with their own?

However, it is not straightforward to measure the degree of syntactic alignment for one participant while at the same time testing what effect this type of alignment has on their partner's opinion of them. This is because in most studies in which syntactic alignment is measured, prime sentences are not provided by a naïve participant but by a confederate. Using a confederate provides the experimenter with the necessary experimental control: experimenters can ensure that the same number of primes in each condition is presented to all participants in the experiment (hereafter "primed participant"). However, to answer the research question presented above, we cannot include a confederate in our paradigm. A confederate would be aware of the experimental manipulation and therefore would not be able to give unbiased opinions about the primed participants. We thus need the person evaluating the primed participant to also be a naïve participant (hereafter "evaluator"). However, we still need to be able to control the behaviour of this evaluator, to make sure that we present an equal number of primes in each condition to each primed participant. To combat this problem, we developed a new conversation task for two naïve participants, in which one of them (the evaluator) provides the primes for the other participant. Participants are playing a card game in which they describe photographs to each other. We solved the problem of experimental control by instructing the evaluator to read out sentences written underneath the photographs, while the other is freely describing them. This way, we can test two naïve participants and measure the degree of syntactic alignment for one while getting usable evaluations from the other, without losing experimental control.

In sum, we hypothesize that in a situation in which it is important to be evaluated positively by another person (e.g. a job interview or a first date) speakers automatically adapt how much they align with their partner's syntactic choices. Based on previous literature, however, it is unclear whether these speakers will show weaker or stronger alignment effects than speakers who feel less pressure to impress their partner. On the one hand, studies suggest a positive influence of likeability of the partner on the strength of syntactic alignment (Balcetis & Dale, 2005; Lev-Ari, 2015) while on the other hand, others have reported that the more speakers like or want to be liked by their partner, the *weaker* their syntactic alignment magnitude (Coyle & Kaschak, 2012; Weatherholtz et al., 2014). Crucially though, we expect that if it is the case that speakers who feel more pressure to impress their partner are more likely to align their syntactic choices with their partner's structures, their partners will also evaluate them more favourably when they show stronger priming effects, and vice versa. In other words, we test whether syntactic alignment is actually an effective way to make your conversation partner like you.

In the experiments described below, we always paired two naïve participants. One of them is assigned the role of the primed participant, the other the evaluator. The primed participant freely describes photographs with active or passive sentences, whereas the evaluator reads out sentences that are written underneath the photographs (unknown to the primed participant). For the primed participants, we expect a syntactic priming effect for passive primes: we expect that participants are more likely to produce passive descriptions when their partner has produced a passive sentence to describe the previous photograph than after baseline trial - a sentence with an intransitive verb. In line with other studies focusing on response tendencies in transitive sentences (Bernolet et al., 2009; J. K. Bock, 1986; K. Bock & Loebell, 1990; Hartsuiker & Kolk, 1998), we do not expect such an effect for active primes. More specifically, we expect a ceiling effect in the baseline frequency of producing actives in our native Dutch participant group (Segaert et al., 2011), due to which a priming effect cannot be detected. We manipulated between-subjects whether the primed participant feels the need to be evaluated positively. In Study 1, half of the primed participants interact with a partner who they know is going to evaluate them later. As a control, the other half of the primed participants do not know their partner is going to evaluate them after the experiment. By comparing the two groups, we can test whether having the social goal to be evaluated positively influences how much the primed participants align their syntactic choices with their partner's prime structures. The evaluator will rate the primed participant before and after the experiment, allowing us to then use these ratings to assess whether syntactic alignment effectively influences likeability. Based on the results of this study, we conducted a second, follow-up study which will be introduced and described after presenting the methods and results of Study 1 below.

4.2. Study 1

4.2.1. Method

4.2.1.1. Participants

We tested 120 voluntary, naïve participants (mean age: 21.1 years, SD: 2.39, 27 males). Participants were always scheduled in pairs, so there were 60 pairs. Individuals in a pair did not know each other before the start of the experiment. Pairs were randomly assigned to one of two experimental contexts: *Control* or *Evaluation* (see below). For each pair in each context, one participant was randomly assigned the role of *evaluator*, providing the primes for the participant (see below). The other participant was the *primed participant*, for whom we measured syntactic priming magnitude. One participant pair in the Control context was excluded from the analyses because the testing conditions were not identical to all other pairs: there were three experimenters present, as opposed to only one experimenter for the rest of the pairs. We thus analysed data for 29 pairs in the Control context and 30 pairs in the Evaluation context. In the Control context, there were two male-male pairs and 16 female-female pairs. There were also 11 mixed pairs; for seven of these pairs the female participant was assigned the role of evaluator. In the Evaluation context, there was one male-male pair and there were 18 female-female pairs. There were again 11 mixed pairs; for three of these pairs the female participant was assigned the role of evaluator. All participants were native Dutch speakers and were monetarily compensated for their participation. All participants gave written informed consent in accordance with the declaration of Helsinki. The study was approved by the local Ethics Committee of the Social Sciences faculty of the Radboud University (Ethics Approval Number ECG2013-1308-120).

4.2.1.2. Materials

The photographs used in this experiment have been described extensively elsewhere (e.g. Segaert et al., 2011). All photographs depicted one or two actors performing an intransitive (e.g. running) or a transitive (e.g. kissing, strangling) action, respectively. Photographs were printed on individual cards. Participants each got one deck of cards. Each deck consisted of 240 unique cards; the pictures used in both decks are identical. There were 160 cards with transitive photographs. Agent and patient roles were depicted by either a pair of adults or a pair of children, always one male and one female actor. There were 40 transitive actions depicted, each one once with the male child actor, once with the male adult actor, once with the female child actor and once with the female adult actor as the agent. Transitive cards could be described with a sentence in the active or passive voice. Transitive cards functioned as primes (when described by the evaluator) or targets (when described by the primed participant). There were also 80 intransitive cards. Intransitive actions were depicted by the same actors depicted on the transitive cards and served as filler items and baseline primes.

4.2.1.3. Between-pairs manipulation: Control versus Evaluation context

To test whether the magnitude of syntactic alignment is influenced when participants feel the need to impress their conversation partner, we manipulated the social status of the evaluator. For the pairs assigned to the Evaluation context, we told *both* participants before the start of the experiment that one of them would take on the role of an evaluator, who would evaluate the other after the experiment was finished. Thus, for both participants, it was clear that they were not equals in this experiment. We did stress that the task would be the same for both participants (even though it was not: see below). For the other half of the participant pairs (i.e. participants in the Control context), we did not tell the primed participants anything about the evaluative component of this study, and the evaluators were told in secret (see below). In the Control context, the evaluator thus knew that their partner believed both participants to be equal. This is in contrast with the Evaluation context, where the evaluator knew that the primed participant knew he or she was going to be evaluated by the evaluator. Thus, there was a Context manipulation for primed participants as well as evaluators. Task and procedure were identical in Evaluation and Control context, but different for the evaluator and the primed participant.

4.2.1.4. Task & Design

In both contexts, participants were asked to take turns describing the cards and listening to their partner's description of the cards. Each participant had their own deck of 240 cards of which any six were facing upwards at any one time. The participants’ view of their partner's set of cards was blocked by a divider (Figure 4.1). When it was their turn to describe a card, participants would freely pick one of the six cards in front of them to describe. This was true for both evaluator and primed participant. The partner who was listening (which switched from trial to trial) checked whether the description matched with one of their own six cards. If so, both participants removed the card and replaced it with a new one from their deck. Both participants thus always had six face-up cards in front of them. After this, the other participant would pick a card from the six face-up cards in front of them and describe it, with their partner checking whether the description matched with one of their own six cards. This turn-taking continued until all cards had been described. Since each deck consisted of 240 cards and participants took turns describing them, each partner described 120 cards. Decks were ordered identically for both partners to make sure they would not describe the same card twice.

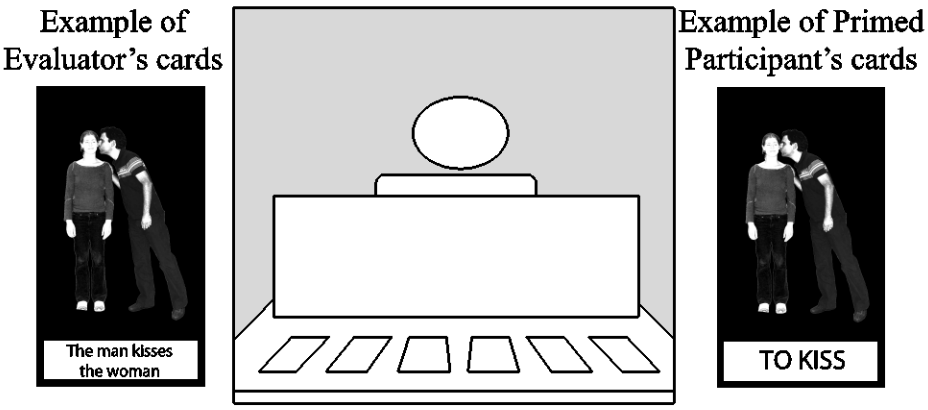

Figure 4.1. Experimental setup and materials. Middle: view for one of the participants (evaluator or primed participant). Paired participants sat across from each other at a table, with a divider between them so they could not see each other's cards. The evaluator's cards (left) showed a photograph and a description sentence. Evaluators were instructed to read out these sentences when it was their turn to describe a card. The primed participant's cards (right) had a verb written underneath the photograph. Primed participants were instructed to use this verb when they described the photograph. All materials were presented in Dutch; examples have been translated to English. Consent for publication was obtained from the actors depicted in the stimuli.

Primed Participant

The participants who were assigned the role of primed participant completed a free-choice syntactic priming task. When it was the primed participant's turn to describe a card, they had to describe it with a single, concise sentence, using the verb written underneath the photograph (see Figure 4.1: e.g. *"The man kisses the woman"* or *"The woman is kissed by the man"*). During listening trials, participants checked whether the card that was described by their partner was in the set of six face-up cards. If so, they let their partner know. Both partners then removed the card and replaced it with a new card from their deck.

Evaluator

The participants who were assigned the evaluator role provided the primes for the primed participant. Therefore, their cards had single, concise sentences already written out underneath the photographs (Figure 4.1). Evaluators were instructed to read out the sentences when it was their turn to speak. This way, we could control the number of passive and active primes that were produced by the evaluator. The cards were balanced such that 50% of the transitive sentences were in the active voice and 50% in the passive. Evaluators' task during listening trials was the same as for the primed participant: they had to check whether the described card was in the set of six cards that were face up. Evaluators were instructed not to look at sentence structure during comprehension trials: they had to check whether one of the photographs matched the primed participant's description, not whether the primed participant produced the exact sentence that was written underneath the photograph.

4.2.1.5. Questionnaires

To assess the influence of syntactic alignment on the likeability of the primed participant, we let evaluators fill in a Relationship Questionnaire. This questionnaire is based on the questionnaire used by Weatherholtz et al. (Weatherholtz et al., 2014) and consisted of 7 statements (Table 4.1A). Participants indicated on a 6-point Likert scale how much they agreed with the statements (1: not at all, 6: completely agree). Evaluators filled out the Relationship Questionnaire twice: once before the experiment, to measure their baseline evaluation of their partner, and once after the experiment, to see whether their partner's syntactic alignment behaviour had any effect on their evaluation. Primed participants only filled out the Relationship Questionnaire once, after the experiment. It was however not the case that only the evaluator filled in a questionnaire at the start of the experiment (which would have been suspicious in the Control context). When evaluators filled in the first Relationship Questionnaire, therefore, the primed participant filled in a Conflict Questionnaire (also based on Weatherholtz et al., 2014). Again, this questionnaire consisted of 7 statements (Table 4.1B) and participants had to indicate on a 6-point scale how much they agreed with these statements. We aimed to use the questionnaire results obtained from the primed participants as a possible explanation for individual variation in the strength of primed participants' syntactic alignment effects (similar to Balcetis & Dale, 2005; and Weatherholtz et al., 2014).

4.2.1.6. Procedure

Both participants were picked up from the waiting room together. In the Evaluation context, participant roles were assigned randomly in the presence of the primed participant. The person sitting closest to the door would always be the evaluator. It was then explained to them that the evaluator would be evaluating the primed participant. In the Control context, role assignment information was not openly shared. The rest of the experimental procedure was identical in both conditions, but different for the evaluator and the primed participant. Both participants would first read role-specific instructions. Crucially, in both contexts, the primed participant believed they read the same instructions as their partner, which explained that they should take turns describing the photographs on the cards. However, the instructions for the evaluator explained a different task: to read out the sentences underneath the photographs. The evaluator was asked not to pose any questions about their task in the presence of the other participant. If they did have questions, they were instructed to ask the experimenter if they could go to the bathroom, which functioned as an excuse to go to the hallway with the experimenter in private. They would then get an opportunity to ask questions without the primed participant hearing them. After reading the instructions, there was a practice session (which only consisted of intransitive cards, to ensure there was no opportunity for priming), followed by both participants filling in the first questionnaire. Questionnaires were again role-specific, but the primed-participant believed them to be identical. For the evaluator, the first questionnaire was the baseline evaluation of their partner (Relationship Questionnaire 1). For the primed participant, the questionnaire consisted of statements about their conflict management strategies (Conflict Questionnaire). During the experiment, the experimenter coded both participants' utterances online for correctness (the criteria were that the agent and patient had to be named correctly and the written verb used in the sentence). Coding was later verified by another coder who was unaware of the purpose of the experiment. Only correct target responses were included in the analysis. After completing the experiment, both participants filled out the Relationship Questionnaire (second time for the evaluators). Lastly, participants were debriefed on the purpose of the experiment. None of the primed participants in the Control context were aware during the experiment that they were being evaluated. Also, none of the primed participants noticed that their partner had different cards than they did.

4.2.1.7. Analysis Approach

<u>Questionnaire Data</u>

Principal component analysis (PCA) was used to reduce the number of variables in the questionnaire data.

Relationship Questionnaire Following the advice of Reise et al. (Reise, Ventura, Nuechterlein, & Kim, 2005) on within-participant repetition of questionnaires (as was the case for the evaluators) we conducted multivariate PCA to analyse the Relationship Questionnaire. For component extraction, we combined the questionnaire responses from this experiment with data from two other syntactic priming experiments in which the exact same questionnaires were administered

(Heyselaar, Hagoort, & Segaert, 2014; Schoot et al., in prep). We then conducted multivariate PCA with orthogonal (varimax) rotation using 270 respondents (Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO): 0.77; Bartlett's test of sphericity: $\chi^2(21)$: 964.64, $p < .0001$), who all filled in the questionnaire twice. We used conservative and principled criteria advocated in the statistical literature – a combination of parallel analysis and the Kaiser criterion (extract eigenvalues > 0.1) – to determine the number of factors to be extracted. These criteria indicated that a two-factor model had the greatest explanatory power for the Relationship Questionnaire data. Table 4.1A shows the loadings for each statement in the Relationship Questionnaire. Based on the questions with the highest loadings, we named these factors *Likeability* and *Shyness*.

Conflict Questionnaire For the Conflict Questionnaire we used the standard PCA with orthogonal (varimax) rotation as we did not have to account for repeated measures (KMO: 0.56; Bartlett's test of sphericity: $\chi^2(21)$: 489.17, $p < .0001$). Using a combination of parallel analysis and the Kaiser criterion, it was indicated that a three-factor model had the greatest explanatory power. Table 4.1B shows the loadings for each statement in the Conflict Questionnaire. Based on the questions with the highest loadings, we named these factors *Ignore, Dominate,* and *Compromise.*

Table 4.1. Results of the Questionnaire Principal Component Analyses. (Questions presented in Dutch). Loadings greater than |0.4| are in bold as these items contribute most to the meaning of a factor. Loadings less then |0.1| are omitted for clarity.

1A. Relationship Questionnaire	Factor 1	Factor 2
	Likability	Shyness
I could be friends with my partner	0.69	0.41
My partner is similar to me	0.68	
My partner appeared generous	0.68	0.28
My partner intelligent	0.68	
My partner appeared selfish	-0.23	-0.64
My partner appeared shy	-0.11	0.83
My partner appeared enthusiastic	0.72	-0.28
Proportion Explained	*0.63*	*0.37*

1B. Conflict Questionnaire	Factor 3	Factor 4	Factor 5
	Ignore	*Dominate*	*Compromise*
I ignored the conflict and behaved as if nothing had happened	-0.94		
I pretended there was no conflict	0.92		
I tried to find a middle ground	0.14	-0.18	0.88
I had a discussion with the other person to try to find a middle ground	-0.28	0.22	0.78
I insisted that it wasn't my fault	0.12	0.70	-0.16
I kept pushing until the other person saw that I was right		0.82	
I tried to convince the other person that my solution was the best	-0.17	0.79	0.16
Proportion Explained	*0.36*	*0.36*	*0.28*

Syntactic choices of Primed Participant

The goal of the analyses of the primed participant's target responses was two-fold. First, it functioned as a check to see whether we could measure reliable syntactic priming effects in primed participants with our new paradigm in which we used a naïve participant instead of a confederate. Secondly, we wanted to see whether there was a difference in the degree of syntactic alignment between participants in the Control and Evaluation contexts. We analysed the primed participant's target responses with a generalized linear mixed effects model, using the glmer function of the lme4 package (Bates, Mächler, Bolker, & Walker, 2014) in R (R Core Team, 2014).. Three conditions were included in the analysis under the factor *Prime*: baseline trials (intransitive prime followed by a transitive target), active priming (active prime followed by a transitive target), and passive priming (passive prime followed by a transitive target). Target responses were coded as 0 for actives and 1 for passives. We used a maximal random-effects structure (Barr et al., 2013): the repeated-measures nature of the data was modelled by including a per-participant and per-item random adjustment to the fixed intercept ("random intercept"). We began with a full model and then performed a step-wise "best-path" reduction procedure, removing interactions before main effects, to locate the simplest model that did not differ significantly from the full model in terms of variance explained. The full model included fixed effects for *Prime* and *Cumulative Passive Proportion* (see below) and two-way interactions between *Prime* and *Context, Cumulative*

Passive Proportion and *Context,* and *Prime* and extracted factors (Relationship: *Likeability* and *Shyness*; and Conflict: *Ignore, Dominate* and *Compromise*). Since we had no *a priori* hypotheses about a gender effect on syntactic alignment in the current study, we did not include any main effects or interactions with this factor in our model. The factorial predictor *Prime* was dummy coded (all means compared to a reference group: intransitive baseline trials). For categorical predictors with two levels we used sum contrasts. All numeric predictors were centred.

<u>Ratings of Evaluator</u>

We secondly tested whether evaluators' ratings of their partner were influenced by how strongly their partner aligned with their syntactic choices. To this end, we first calculated for each evaluator the difference in their score on each component extracted from the Relationship questionnaire (*Likeability* and *Shyness*), as measured before and after the experiment. Since we subtracted evaluators' scores before the experiment from the same evaluators' scores after the experiment, a positive difference score indicates that evaluators evaluated their partner as more likeable or more shy after the experiment.

We then calculated the degree of syntactic alignment for each primed participant (the proportion of passive targets following a passive prime minus the proportion of passive targets following a baseline prime). Together with the factor *Context* (Control vs Evaluation), the magnitude of the primed participant's syntactic alignment effect was entered in linear regression models to predict the corresponding evaluator's difference in evaluation of the primed participant. Two models were run, with the two difference scores (one for each of the components) as dependent variables.

4.2.2. Results

The evaluators in the Control context produced on average 29.28 (SD: 8.04) baseline primes, 29.62 (SD: 4.55) active primes and 25.2 (SD: 4.11) passive primes. The evaluators in the Evaluation context produced on average 30.30 (SD: 8.29) baseline primes, 28.60 (SD: 3.94) active primes and 24.00 (SD: 4.24) passive primes. A repeated measures ANOVA shows no significant effect of *Context* and no significant interaction *Context * Prime* (both $p > 0.5$). There is a significant main effect of *Prime* (F (2,114) = 11.47, $p < 0.001$): evaluators were generally less likely to pick the cards with a passive description than the cards with an active or a baseline description. This reflects their natural preference for active sentence production in daily life. On average though, the evaluators still produced 24.6 passive primes: this was sufficient for our experimental manipulation.

4.2.2.1. Syntactic choices of Primed Participant

Our full model included the fixed factors *Context, Prime,* the cumulative proportion of passives produced up until that trial (*Cumulative Passive Proportion),* and the primed participant's scores for *Likeability, Shyness, Compromise, Dominate* and *Ignore*. Using the step-wise 'best path' reduction procedure we arrived at a final model which only included fixed factors *Cumulative Passive Proportion* and *Prime*, and a random by-participants slope for *Prime*. This model was not significantly different from the full model (Full model = AIC: 1167.6 BIC: 1401.0; Best model = AIC: 1136.0 BIC: 1207.4, $p = .8251$). The results from this final mixed model are reported in Table 4.2. In line with previous findings in the literature, there is a significant effect of *Passive Prime* ($p < .001$): as can be seen from Figure 4.2 (left panel), the percentage of passive descriptions participants produced is higher for target pictures preceded by a passive prime (Control: 8.41% ± 1.61% (mean ± SE); Evaluation: 5.08% ± 1.19%) than for target pictures that were preceded by an intransitive prime (Control: 1.48% ± 0.48%; Evaluation: 1.92% ± 1.13%). Hence, there is a syntactic alignment effect for passives: participants produce more passives after passive primes relative to intransitive primes (Figure 4.2 (right panel): Control: 6.93% ± 1.52%; Evaluation: 3.16% ±1.05%). As expected, results show no syntactic alignment effect for actives: there were not more actives produced following active primes relative to baseline primes.

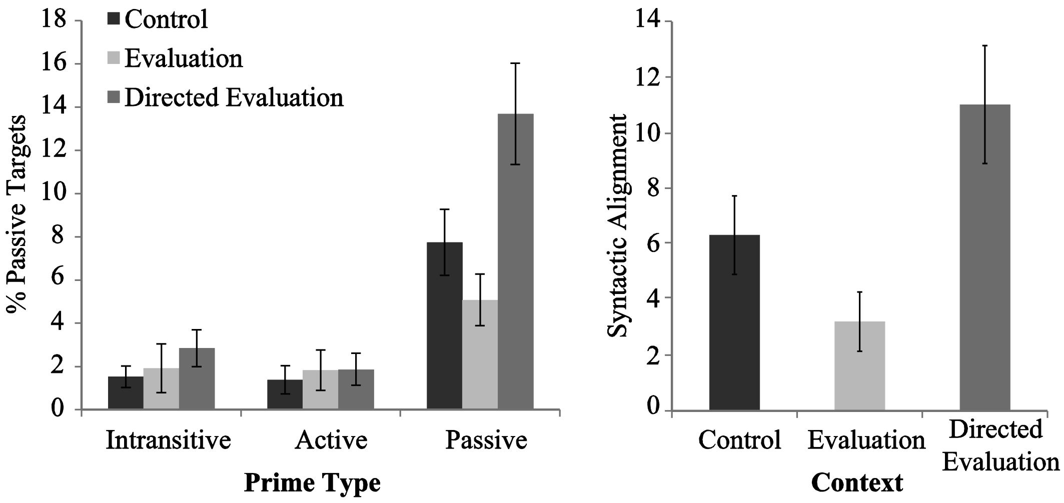

Figure 4.2. Results syntactic choices primed participants (1). Left: Average percentage of passive targets produced by the primed participants after an intransitive, active or passive prime by the evaluator, for Control, Evaluation and Directed Evaluation contexts. Right: Average degree of syntactic alignment, the percentage of passive target descriptions produced after a passive prime relative to baseline (intransitive primes), split for primed participants in the Control, Evaluation and Directed Evaluation context. All error bars represent standard errors from the mean. Note that the set-up and results of the Directed Evaluation context in Study 2 will be described and discussed in detail later on in the paper, but are depicted here for easy comparison between studies.

Table 4.2. Results syntactic choices primed participants in Control and Evaluation Contexts: general linear mixed effects model

Predictor	Coefficient	*SE*	*Wald Z*	*p*
Intercept	-5.66	0.54	-10.51	< .001
Active Prime	-1.14	0.93	-1.22	.224
Passive Prime	2.34	0.53	4.45	< .001
Cumulative Passive Proportion	1.73	1.17	1.48	.138

Note: N = 4831, log-likelihood = -557.0

It should be noted here that the factor *Context* (Evaluation / Control) is not included in the final model. The same holds for the factors representing the primed participants' scores on the components *Likeability, Shyness, Compromise, Dominate* and *Ignore*. This is due to the fact that we used a step-wise "best path" model reduction procedure: these factors did not significantly improve the variance explained by the model ($p > .05$) and were therefore removed from the model.

Importantly, this indicates that there was no significant effect of Context on the magnitude of syntactic alignment effects. Nevertheless, Figure 4.2 suggests that on average, participants in the Evaluation condition show weaker syntactic alignment than participants in the Control context. However, although standard practice, bar graphs based on averages and standard errors might not be the best way to plot group differences in this type of effects. Bar graphs obscure individual variation between participants, while linear mixed effects models do take this individual variation into account (see also Weissgerber, Milic, Winham, & Garovic, 2015). Therefore, we plotted the effect of passive priming for each individual participant in each context (Figure 4.3, A and B). In this plot, we can clearly see that there is indeed a lot of individual variation in how susceptible participants are to syntactic priming. The difference between groups as suggested by the bar graph in Figure 4.2 is likely driven by just a few participants in the Control context that show a very strong syntactic alignment effect, and a few participants in the Evaluation context that show a negative effect (more passive targets after intransitive primes than after passive primes).

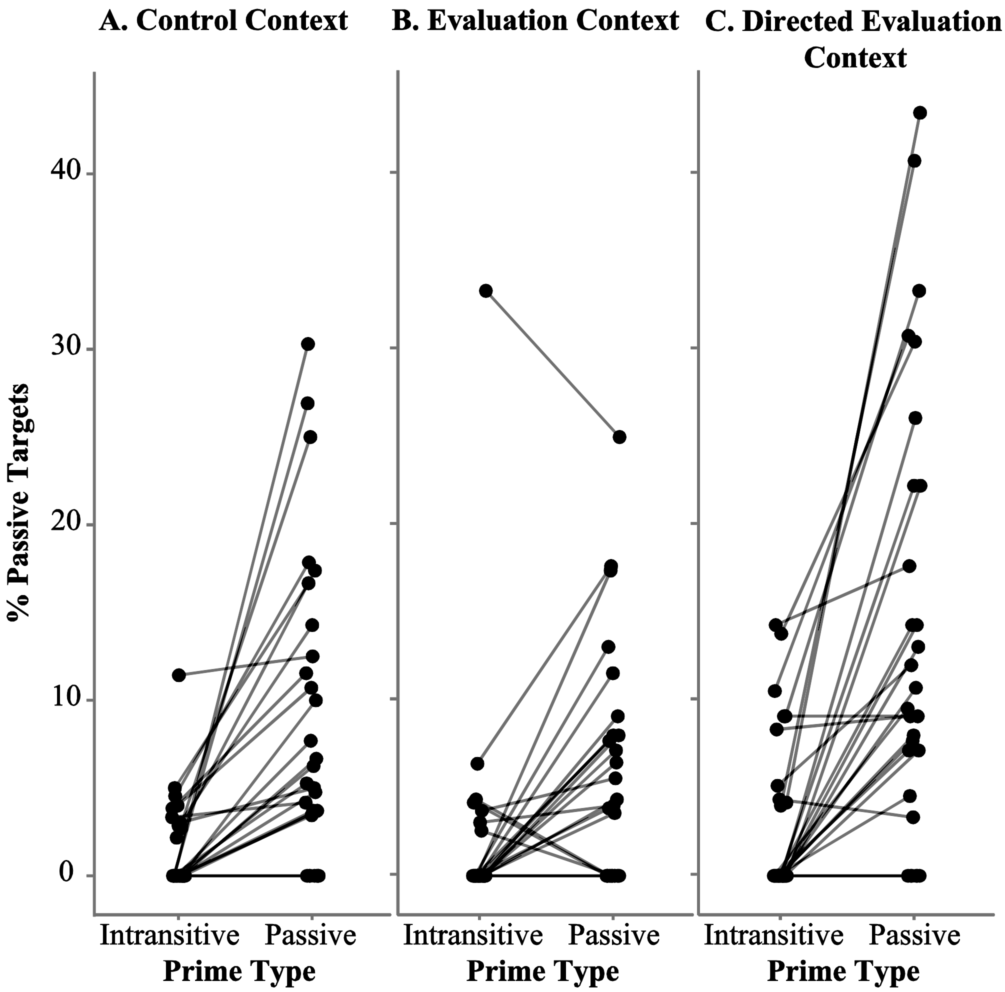

Figure 4.3. Results syntactic choices primed participants (2). Syntactic priming effect per primed participant in Control (A), Evaluation (B) and Directed Evaluation (C) contexts. For each participant, the percentage of passive targets after intransitive and passive primes is plotted. Lines connect data points from the same individual. Therefore, lines that have a positive slope indicate that participants produce more passive targets after a passive prime than after an intransitive prime: this participant shows a syntactic priming effect. Although the Directed Evaluation Context will not be discussed in Study 1, in order to allow a direct comparison between all contexts, we chose to present the data from all contexts in one figure. For more details on the Directed Evaluation context, see Study 2.

4.2.2.2. Ratings of Evaluator

For each evaluator, we calculated the difference in how they evaluated their partner before and after the experiment, based on the extracted components *Likeability* and *Shyness*. Data for one evaluator in the control condition was removed because the difference score for two of the components was more than three SD above the group mean. We first ran a repeated measures ANOVA to check whether evaluators in the Control and Evaluation context differed in their initial evaluations of the primed participant. Results show that this was not the case. There is no main effect of *Context* (Control / Evaluation) and no interaction *Context* * *Component* (all $p > .1$). This means that the two groups which were sampled from the same student population were comparable before they were exposed to our manipulation.

To test whether the difference scores (i.e. evaluation after the experiment minus evaluation before the start of the experiment) are predicted by the strength of syntactic alignment of the primed participant, we performed a linear regression analysis in R, with the evaluator's difference score (centred) as a dependent variable. Independent variables were the *Alignment Magnitude* of the primed participant that evaluators interacted with and *Context* (Evaluation / Control). As can be seen from Table 4.3, for *Likeability*, we find a significant *negative* main effect of *Alignment Magnitude* ($p < .01$). As visualized in Figure 4.4 (A and B), the more the primed participant aligned their syntactic choices with the evaluator, the more the paired evaluator's rating of how likeable the primed participant was decreased. In other words, syntactic alignment seems to lead to a decrease in likeability. There was no significant interaction of *Alignment Magnitude* by *Context* and there were no significant main effects or interactions for the Shyness component (all $p > .1$).

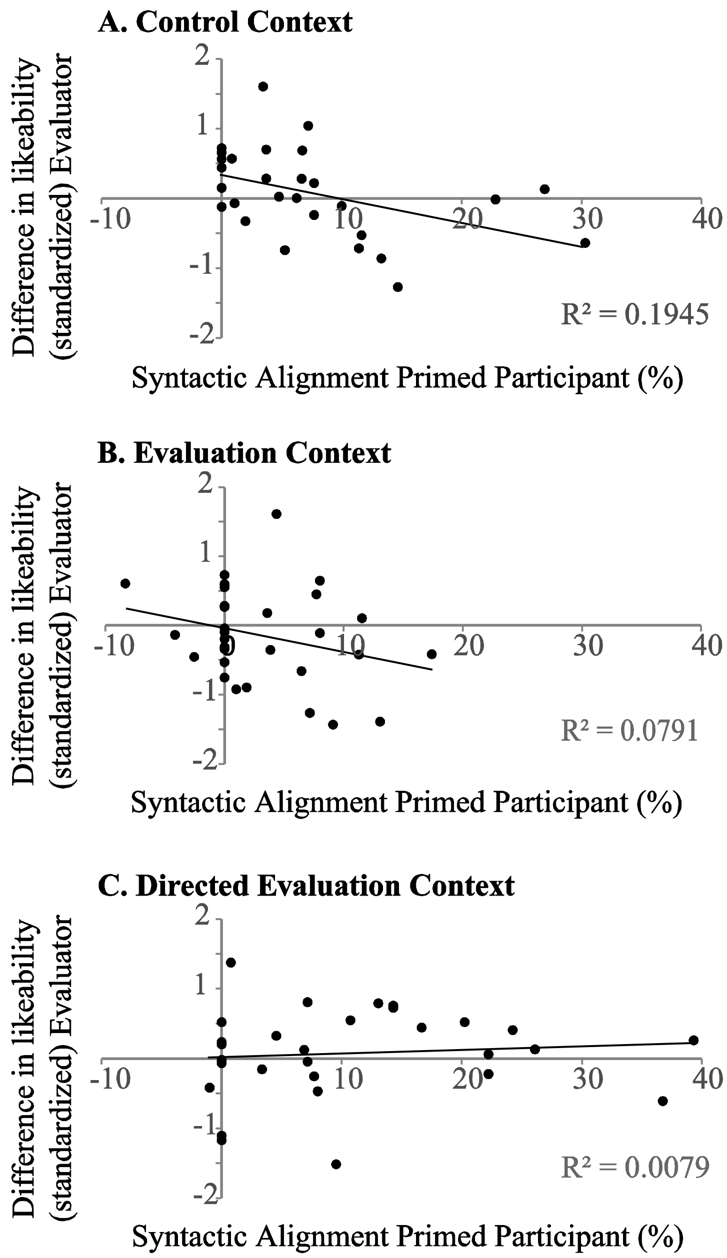

Figure 4.4. Results Evaluators ratings. The effect of the degree of syntactic alignment by the primed participant on *Likeability* as indicated by the evaluator in the Control (A), Evaluation (B) and Directed Evaluation (C) contexts. In Study 1 (Control Context (A) and Evaluation Context (B)), syntactic alignment magnitude of the primed participant has a negative effect on how the evaluator's likeability ratings of the speaker change after the experiment: evaluators decrease their rating when their partners align more with their prime structures. In study 2 (Directed Evaluation context (C)) there is no significant relationship between syntactic alignment and perceived likeability. Again, although the Directed Evaluation context is not discussed in Study 1, to allow a direct comparison between contexts, results are combined into one figure.

Table 4.3. Results ratings Evaluators in Control and Evaluation Contexts. Summary linear regression analysis with difference in *Likeability* (after experiment minus before experiment) ratings from the evaluator as dependent variable and *Alignment Magnitude Partner* and *Context* (Control / Evaluation) as independent variables. Starred effects are significant after correcting for multiple comparisons (we ran the same analyses for two outcome variables: *Likeability* and *Shyness*).

	B	*SE*	*t*	*p*
Intercept	0.15	0.11	1.43	.157
Alignment Magnitude Partner	-3.44	1.28	-2.69	.009 *
Context	0.19	0.11	1.83	.073
Context * Alignment Magnitude Partner	0.01	1.28	0.01	.996
Adjusted R-squared: 0.112				

4.2.3. Discussion Study 1

Study 1 was designed to investigate how participants adapt their language behaviour in situations where they perceive themselves and their partner to be equals (Control context), compared to when they know they are being evaluated by their partner (Evaluation context). We assumed that in the Evaluation context, the primed participants would try to be rated favourably by an evaluator. Thus, we investigated the influence of having a social goal to make their conversation partner evaluate them positively on the degree of speakers' alignment with their conversation partner's syntactic structures. Moreover, we tested whether this is effective: does syntactic alignment actually contribute to the conversation partner's evaluation of the speaker?

To address the latter question, we let evaluators rate their partner before and after the experiment. We found that the relationship between how much primed participants aligned their syntactic choices with the evaluator's prime structures and the change in how that evaluator evaluated them on the likeability component of our questionnaire before and after the experiment was *negative*. In other words, the more the participants aligned their syntactic choices with their evaluator's prime structures, the more evaluators decreased their *Likeability* rating after the experiment (compared to before the start of the experiment). This is in line with Coyle and Kaschak's suggestion that not aligning with a partner's syntactic choices may be taken as a display of creative behaviour of the speaker (Coyle & Kaschak, 2012). Although Coyle and Kaschak focus on creative behaviour as an attractive quality for potential mates, based on the results of Study 1, it seems likely that displaying creative behaviour (i.e. no syntactic alignment) influences the likeability of speakers in other situations as well. We argue that it is for this reason that we found a negative relationship between the primed participant's syntactic alignment magnitude and the evaluator's ratings. Indeed, the results of Study 1 alone suggest that in any context, irrespective of how explicit the evaluative component of the context is, evaluators appreciate creative language behaviour more than repetitive linguistic choices.

In light of the evaluators’ results and the interpretation we have provided above, we would expect that primed participants in the Evaluation context would align less strongly with the syntactic structures of their evaluator than primed participants in the Control context. Although the bar graphs presented in Figure 4.2 suggest that on average, this was indeed the case, Figure 4.3 shows that this effect is driven by only a few participants. Indeed, we found no significant *Prime* by *Context* interaction: syntactic alignment was not stronger or weaker in the Evaluation context compared to the Control context.

However, based on these results, we cannot draw the conclusion that the desire to be evaluated positively by their conversation partner does not influence the magnitude of syntactic alignment of a speaker. Apart from the fact that any null result should always be interpreted with caution, we want to address one possible caveat of our study that might explain why we do not find any significant group level effects. We will address this issue in a follow up study described below. Of course there are other possible explanations for our null result: we will return to these in the General Discussion section of this paper.

A possible caveat of Study 1 was that although we told primed participants in the Evaluation context that they would be evaluated by their partner after the experiment ("your partner will tell us what he/she thinks about you"), we did not explicitly tell them it was important to make their partner like them. We assumed that by telling primed participants that they would be evaluated by their partner after the experiment, they would automatically and unconsciously do their best to make their partner evaluate them positively. However, there might have been individual variation between primed participants with respect to how much they valued to be evaluated positively by their partner. Perhaps group effects would have been stronger if we would have set an explicit goal for all primed participants in the Evaluation context to make their partner evaluate them *positively*. We would then expect that participants in the Evaluation context would show weaker alignment with their partner's prime structures than participants in the Control context. This would both be in line with results by Coyle and Kaschak (Coyle & Kaschak, 2012) as with our finding that strong syntactic alignment has a negative effect on how likeable speakers appear to their partner. Even more, Figure 4.3 shows that there were a few participants in the Evaluation context that show anti-alignment (less targets described with a passive after a passive prime compared to baseline), whereas none of the participants in the Control context showed such an effect. Although purely speculative, this might mean that some participants in the Evaluation context were indeed trying harder than others to make their partner like them, but that the manipulation is not strong enough to surface at the group level.

In Study 2, we address this issue. The design of Study 2 is almost identical to the Evaluation context in Study 1, with the exception that in Study 2, we explicitly tell the primed participants to make a positive impression on their partner. Based on the results reported in Study 1, we hypothesize that if syntactic alignment is influenced by the social goals of the speaker, explicitly telling participants to make a positive impression on their partner will lead to a decrease in the magnitude of syntactic alignment, relative to the Control context reported above. By changing as little as possible to the design, Study 2 additionally allows us to test whether we can replicate the negative effect of syntactic alignment of the primed participant on the change in likeability ratings of the evaluator they are paired with.

4.3. Study 2

4.3.1. Method

4.3.1.1. Participants

In Study 2, we tested an additional 60 voluntary, naïve participants (mean age: 21.9 years, SD: 5.02, 12 males). All participants met the same exclusion criteria as specified in Study 1. There were 30 pairs. Individuals in a pair did not know each other before the start of the experiment. One participant pair was excluded from further analyses because the ratio of active/passive primes produced by the Evaluator was significantly different from all other pairs. We thus analysed data for 29 pairs in Study 2. There was one male-male pair and 19 female-female pairs. There were also 9 mixed pairs; for 7 of these pairs the female participant was assigned the role of evaluator.

4.3.1.2. Task, Design & Procedure

From the perspective of the evaluators, the task, design and procedure for Study 2 were identical to the Evaluation context in Study 1. The only difference between the Evaluation context in Study 1 and Study 2 was in the instructions that were given to the primed participant. As in the Evaluation context in Study 1, both participants in the pairs in Study 2 knew that there was one evaluator who was going to evaluate the primed participant after the experiment. However, in Study 2, primed participants were presented with additional written instructions to try to make a positive impression on their partner. The evaluator was not aware of this additional task for the primed participant; therefore, the instructions of the evaluator were identical to those in Study 1. We told the primed participants that the goal of the experiment was to investigate which aspects of social interaction influence how people are evaluated by their partner. Crucially, they were told that the only way to make a positive impression on their partner was in the way they described the cards - they were not allowed to engage in any type of additional verbal interaction with their partner (e.g. making jokes). From now on, we will refer to the participants who were tested in Study 2 as the participants in the 'Directed Evaluation context'.

After completing the experiment, primed participants filled in a *post-hoc* questionnaire in which we checked whether they actually tried to make a positive impression on their partner, and if so, whether they had used a specific strategy. Crucially, all primed participants answered that they had tried to make a positive impression on their partner, but none of the participants indicated they had consciously used syntactic repetition as a strategy.

4.3.1.3. Analysis Approach

Questionnaire Data

We used the same component loadings used in Study 1 to calculate component scores for the questionnaire data of the participants in Study 2.

Syntactic choices of primed participant

For the primed participants, we compared the strength of syntactic alignment of the primed participants in the Control context, Evaluation context and the Directed Evaluation Context. (The former two were measured in Study 1 and the latter was measured in Study 2). We analysed the primed participant's target responses with a generalized linear mixed effects model. Model specifications remain unchanged with respect to the specifications that were reported in the Analysis Approach section for Study 1, with the exception that the predictor *Context* now has three levels. This factor was therefore dummy-coded (all means compared to a reference group: Control context). Again, we used a maximal random-effects structure and began with a full model and then performed a step-wise "best-path" reduction procedure, removing interactions before main effects, to locate the simplest model that did not differ significantly from the full model in terms of variance explained.

Ratings of Evaluator

A second goal of Study 2 was to replicate the negative effect of syntactic alignment of the primed participants on the evaluators' rating. To this end we calculated for each evaluator the difference in their score on each component extracted from the Relationship questionnaire (*Likeability* and *Shyness*), as measured before and after the experiment and the degree of syntactic alignment for each primed participant. Together with the factor *Context* (Control / Evaluation / Directed Evaluation), the magnitude of the primed participant's syntactic alignment effect was entered as a predictor in two linear regression models, one for each of the components as dependent variables. The factor *Context* was dummy-coded (all means compared to a reference group: Control context).

4.3.2. Results

The evaluators in Study 2 produced on average 30.17 (SD: 6.82) baseline primes, 31.10 (SD: 4.90) active primes and 22.79 (SD: 4.81) passive primes. To compare these prime type ratios to the Control and Evaluation contexts, we ran a repeated measures ANOVA with between-subjects factor *Context* (3 levels) and within-subjects factor *Prime* (3 levels). Results show that there is no significant effect of *Context* and no significant interaction *Context* * *Prime* (both $p > .5$). Again, we find a significant main effect of *Prime* (F (2,170) = 24.87, $p < .001$): evaluators were generally less likely to pick the cards with a passive description than the cards with an active or a baseline description. This reflects their natural preference for active sentence production in daily life.

4.3.2.1. Syntactic choices of Primed Participant

Our full model included the fixed factors *Context, Prime,* the cumulative proportion of passives produced up until that trial (*Cumulative Passive Proportion),* and the primed participant's scores for *Likeability, Shyness, Compromise, Dominate* and *Ignore*. Using the step-wise 'best path' reduction procedure we arrived at a final model that only included fixed factors *Cumulative Passive Proportion* and *Prime*, and a random by-participants slope for *Prime*. This model was not significantly different from the full model (Full Model = AIC: 2014.8 BIC: 2345.5; Best Model = AIC: 2023.1, BIC: 2099.1; p =.127). The results from this final mixed model are reported in Table 4.4. In line with our previous findings and other findings in the literature, there is a significant effect of *Passive Prime* ($p < .001$, Figure 4.2): the percentage of passive descriptions participants produced is higher for target pictures preceded by a passive prime (13.7% ± 2.29%) than for target pictures that were preceded by an intransitive prime (2.85% ± 0.83%). Hence, there is a syntactic alignment effect for passives: participants produced more passives after passive primes relative to intransitive primes. As expected, results show no syntactic alignment effect for actives: there were not more actives produced following active primes relative to baseline primes.

Similar to Study 1 the factor *Context* (Directed Evaluation / Evaluation / Control) is not included in the final model. This is due to the fact that we used a step-wise "best path" model reduction procedure: the factor *Context* did not significantly improve the variance explained by the model ($p > .05$) and was therefore removed from the model. This indicates that there was no significant effect of *Context* on the magnitude of syntactic alignment effects. As can be seen from Figure 4.2, there does seem to be trend for more syntactic alignment in the Directed Evaluation context compared to Control and Evaluation but this is again due to only a couple of participants (Figure 4.3C).

Table 4.4. Results syntactic choices primed participants in Control, Evaluation and Directed Evaluation contexts: general linear mixed effects model

Predictor	Coefficient	*SE*	*Wald Z*	*p*
Intercept	-5.36	0.42	-12.63	< .001
Active Prime	-1.23	0.73	-1.69	.091
Passive Prime	2.46	0.42	5.95	< .001
Cumulative Passive Proportion	1.94	0.98	1.99	.047

Note: N = 7354, log-likelihood = -1000.6

4.3.2.2. Ratings of Evaluator

Contrary to our expectations, we did not find a negative effect of *Syntactic Alignment* magnitude on the ratings of the Evaluator in the Directed Evaluation context. In the Directed Evaluation Context, the degree of syntactic alignment of the primed participants was not a significant predictor for the change in likeability rating as indicated by the evaluator they were paired with (p > .05). Figure 4.4 clearly depicts the interaction Context * Syntactic Alignment for the Likeability component (p = .0360, see Table 4.5): although there is a negative effect of syntactic alignment on perceived likeability for participants in the Control and Evaluation context, in the Directed Evaluation context this effects disappears. Syntactic alignment of the primed participant was also not a significant predictor for the difference score on the *Shyness* component of the questionnaire nor was there an effect of Context for this component (all p > .05).

Table 4.5. Results ratings Evaluators in Control, Evaluation and Directed Evaluation contexts. Summary linear regression analysis with difference in *Likeability* (after experiment minus before experiment) ratings from the evaluator as dependent variable and *Alignment Magnitude Partner* and *Context* (Control / Evaluation/Directed Evaluation) as independent variables.

	B	*SE B*	*t*	*p*
Intercept	0.34	0.16	2.09	.040
Alignment Magnitude Partner	-3.43	1.51	-2.28	.025
Evaluation Context	-0.38	0.21	-1.81	.075
Directed Evaluation Context	-0.32	0.23	-1.38	.171
Evaluation Context * Alignment Magnitude Partner	-0.01	2.59	-0.01	.996
Directed Evaluation Context * Alignment Magnitude Partner	3.94	1.85	2.13	.036
Adjusted R-squared: 0.064				

4.3.3. Discussion Study 2

Study 2 again showed that we can replace a scripted confederate with a naïve participant and still obtain reliable syntactic priming effects for primed participants. However, there was a crucial difference between Study 1 and 2. In Study 1, we compared the syntactic alignment magnitude of primed participants in an

Evaluation context with the alignment magnitude of participants for whom the evaluator appeared to be another naïve, socially equal participant (Control context). We did not find a difference between the degree of syntactic alignment of primed participants in these two contexts. To exclude the possibility that this null result was due to individual variation in primed participants' sensitivity to the social status manipulation and their desire to be evaluated positively by their partner, in Study 2, we explicitly told the primed participants to try to make a positive impression on their partner. As in Study 1, the analysis of Study 2 did not show a significant effect of Context on the magnitude of syntactic alignment of the primed participants. However, based on a *post-hoc* questionnaire, we can be certain that all primed participants did try to make a positive impression on their partner. We can therefore exclude the possibility that the lack of a main effect of Context in Study 1 was due to the fact that there was too much individual variation between the primed participants' desires to be evaluated positively by their conversation partner. Indeed, if this were true, we should have found a significant difference between the alignment effects of primed participants in the Control context in Study 1 and the primed participants in Study 2. More specifically, based on the results of Study 1, we would have expected that participants in Study 2 would align less with their partner's syntactic choices than in the participants in the Control context. We did not find any significant results nor was there any trend in the right direction in line with the hypothesis that speakers align less with their partner in order to make a positive impression on them. Secondly, we did not replicate the negative effect of syntactic alignment on the change in ratings on the likeability component by the evaluators. There might be several explanations for this, which we will discuss in the general discussion section below.

4.4. General discussion

In this study, we investigated whether the degree of speakers' alignment with their conversation partner's sentence structures is influenced by having a social goal to make this conversation partner evaluate them positively. Moreover, we tested whether this is effective: does syntactic alignment actually contribute to the conversation partner's evaluation of the speaker? To be able to address both of these questions simultaneously, we developed a novel syntactic priming paradigm in which two naïve participants interacted with each other. For one of the participants, we measured syntactic alignment with different prime structures (active / passive alternation). Crucially, in our paradigm, prime sentences were not provided by a scripted confederate but by a naïve participant who read out written sentences. This way, we could achieve the experimental control that is necessary for syntactic priming paradigms but at the same time, because we let naïve participants be primers, they could also function as evaluators of the primed participants (contrary to a confederate). Below, we will first discuss the results of the primed participants, before moving on to the effect of syntactic alignment on the evaluator's rating of how likeable primed participants appeared to them.

We found reliable syntactic priming effects for primed participants in all experimental contexts. This suggests that replacing a scripted confederate with a naïve participant does not affect the basic syntactic alignment effect. Primed participants did not notice that their partner was reading out sentences instead of freely describing them, like they did themselves. As expected, we found that priming with an active transitive sentence structure does not change subsequent syntactic choices. Priming with a passive transitive sentence structure on the other hand does result in a priming effect on syntactic choices in subsequent sentences. This is consistent with the literature: priming effects for actives are found to be smaller than for passives, or absent altogether (Bernolet et al., 2009; Bock, 1986; Bock & Loebell, 1990; Hartsuiker & Kolk, 1998). In fact, not only for active and passive transitives but also for many other structural alternatives, priming with the less preferred structure results in stronger syntactic priming effects (i.e. the inverse preference effect: Bernolet & Hartsuiker, 2010; Ferreira, 2003; Hartsuiker, 1999; Scheepers, 2003). Taken together, these results show that our paradigm is suited to systematically investigate the bidirectional relationship between syntactic alignment and social opinion.

In Study 1, we found no effect of context on the strength of syntactic alignment: primed participants who knew they would be evaluated by their partner (Evaluation context) did not show stronger alignment than participants who were not aware of this evaluative component (Control context). However, there was a possible caveat in the design of Study 1 that might have contributed to this null result: although we told participants in the Evaluation condition that they would be evaluated by their partner, we did not tell them it was important to be evaluated positively. Hence, we cannot be sure whether participants actually tried to make a positive impression on their partner. To exclude this possible explanation of our null-finding, we ran a follow-up study. Study 2 was identical to the Evaluation context in Study 1, with the exception that in Study 2, unknown to the evaluator, primed participants were instructed to make a positive impression on their partner. Interestingly, we again found no difference between the syntactic alignment magnitude of the participants in Study 2 and the participants in the Control context (or the Evaluation context) in Study 1. We can therefore exclude the possibility that the null finding in Study 1 was due to the fact that our context manipulation was not explicit enough.

How can we interpret the findings of the two studies together? Although null-effects should always be interpreted with caution, with 30 participant pairs tested in each group, we believe the lack of a between-context significant difference in how strongly primed participants aligned their syntactic choices with their partner's structural choices is not due to a lack of statistical power. Rather, our results seem to indicate that the degree of syntactic alignment is not automatically affected by social goals such as making your partner like you, at least not as it is manipulated in the current study. At the very least, this calls into question the robustness of the effects of social goals on syntactic alignment reported by previous studies (Balcetis & Dale, 2005; Coyle & Kaschak, 2012; Lev-Ari, 2015; Weatherholtz et al., 2014). Coyle and Kaschak (Coyle & Kaschak, 2012), for example, found a negative effect of the speaker's desire to impress their partner on syntactic alignment. One difference between our paradigm and the experimental design used by Coyle and Kaschak was that their manipulation of social goals was based on an intrinsic and unconscious desire of the primed participants to impress their conversation partner (i.e. mating goal), whereas our manipulation was external: we (implicitly or explicitly) tell participants to impress their partner. We cannot exclude the possibility that automatic priming effects such as syntactic alignment are only influenced when speakers are internally motivated to impress their partner: future research may investigate this issue in more detail. However, we also acknowledge the possibility that syntactic alignment might not be influenced by social goals at all. Syntactic alignment effects have been reported for participants in a non-social context, for example when primes and/or targets are presented visually in a reading paradigm (e.g. Pickering & Branigan, 1998,Potter & Lombardi, 1998) or when participants are producing the primes themselves (Bock, 1986; Hartsuiker & Kolk, 1998). This already indicates that syntactic alignment cannot be driven by social goals alone. Rather, there must be a more general cognitive mechanism at play, such as implicit learning (e.g. Chang et al., 2006, 2000; Jaeger & Snider, 2013), residual activation (e.g. Pickering & Branigan, 1998) or a combination of both (e.g. Reitter et al., 2011). In this paper, we tested the hypothesis that social goals may exert a top-down influence on these automatic priming mechanisms. However, we found no evidence to support this hypothesis in the studies reported above.

The lack of a robust relationship between (desired) social relationships and syntactic alignment is also reflected in the effect of alignment on the speaker's perceived likeability as indicated by their partner. In Study 1, we found a negative effect of syntactic alignment on how primed participants are rated by the evaluator on the likeability component of our questionnaire. This result seemed to support the hypothesis that showing creativity in linguistic choices (i.e. not aligning with a partner) is an attractive quality which leads to a positive impression of speakers (Coyle & Kaschak, 2012). However, in Study 2, we did not replicate the negative effect reported in Study 1. Considering the results of Study 1 and 2 together, then, we were thus not able to convincingly show that syntactic alignment is a reliable predictor of how likeable speakers appear to their partner. Certainly, there was no *a priori* reason to predict different results for the two studies. However, we do acknowledge that there was a trade-off between the ecological validity we achieved by including two naïve participants in the design and how much we could control their behaviour. We therefore cannot exclude the possibility that primed participants in the Directed Evaluation context may have acted differently from the participants in the other two contexts, and that this may have obscured the already small effect of syntactic alignment on how likeable they were perceived by their partners. Indeed, it is likely that if there is an effect of syntactic alignment on how speakers are perceived by their partners, it will be subtle and therefore susceptible to inter-subject variation and interactions with other aspects of the conversational context.

From our post-hoc questionnaires, we have anecdotal evidence that participants in Study 2 used various strategies to make a positive impression on their partner: for example, by smiling or talking with a cheerful, positive voice. It is possible that behavioural characteristics like these have interacted with the effect of syntactic alignment on perceived likeability in Study 2, leading to different results than the ones found in Study 1. However, since our study only focused on investigating the effect of syntactic alignment on perceived likeability, we can merely speculate about how between-study differences in primed participants' behaviour that are not related to syntactic choices affect how primed participants were perceived by their partner. Since these would be purely post-hoc speculations, we will not discuss them in much depth here. Instead, we would like to mention a way to address these issues in the future. By letting evaluators interact with an avatar in a virtual reality setting (Heyselaar et al., 2015), one could control the exact behaviour of the 'primed participant', varying only syntactic alignment and keeping all other behaviour constant. However, although the use of avatars would allow investigators to zoom in on the effect of syntactic alignment on social opinion, making sure that any difference in social evaluation is in fact due to a difference in syntactic alignment magnitude alone, such a set-up necessarily requires experimenters to control the avatar's syntactic choices and their alignment effect. To the best of our knowledge, there have been no studies in which the alignment effect of the primed participant is manipulated. This is not surprising: it would be very hard to manipulate alignment behaviour in such a way that it appears natural. More research would be necessary to decide whether and when it is natural for the avatar to align with the participant and when not. This was the main reason why in the current study, we made use of a naive participant: to achieve a naturalistic alignment pattern.

The last point we want to address here is that we did not find an effect of how the primed participant felt about the evaluator on the degree of syntactic alignment. Others have reported such an effect, although the directionality of the results has been inconsistent (Balcetis & Dale, 2005; Weatherholtz et al., 2014). One difference between our study and the studies in which likeability of the partner did have an effect was that in the latter studies, the likeability of the conversation partners participants interacted with was explicitly manipulated. However, again, due to the fact that in this study, we let two naïve participants interact with each other, we had no experimental control over this factor. That is, we did not explicitly manipulate the likeability of the evaluator. Therefore, individual differences between participants with respect to how they feel about their conversation partners might not have been large enough to show a significant effect on syntactic alignment.

To conclude, we have shown that our paradigm, in which prime sentences are not provided by a scripted confederate but by a naïve participant who reads out sentences, can be used to measure syntactic alignment with active/passive prime sentences for primed participants. Crucially, the participant providing prime sentences can at the same time evaluate the primed participant. This allows us to investigate whether syntactic alignment effectively influences what the evaluators think about the primed participants. We also investigated whether the degree of syntactic alignment is influenced by having an external, social goal to positively impress your partner. We undertook this research with the aim to shed new light on the relationship between social goals and syntactic alignment: whereas previous studies have only investigated the influence of social goals on syntactic alignment, we investigated whether syntactic alignment effectively influences conversation partners' perception of the speaker. However, we were not able to demonstrate an effect of social goals on syntactic alignment and our results do not provide convincing evidence that there is an effect of syntactic alignment on perceived likeability. The high ecological validity of our set-up may have contributed to the latter: we cannot exclude the possibility that there is an effect of syntactic alignment on perceived likeability, but that this effect interacts with other aspects of social behaviour which we could not control for in our design. It is clear that the relationship between syntactic alignment and perceived likeability is a complex one. We here aimed to contribute to this field by developing a new paradigm and focusing on a specific and novel aspect of the research question, namely whether syntactic alignment effectively influences conversation partners' perception of the speaker. We expect that many more research observations, with large sample sizes like ours, will be needed to make a sizeable contribution to solving the complex puzzle and in the process come to a full understanding of the relationship between syntactic alignment and likeability as well as the mechanisms governing this relationship.

CHAPTER 5

What can we learn from a two-brain approach to verbal interaction?

Adapted from: Schoot, L., Hagoort, P., & Segaert, K. (2016). What can we learn from a two-brain approach to verbal interaction? *Neuroscience & Biobehavioral Reviews*, *68*, 454-459.

Abstract

Verbal interaction is one of the most frequent social interactions humans encounter on a daily basis. In the current paper, we zoom in on what the multi-brain approach has contributed, and can contribute in the future, to our understanding of the neural mechanisms supporting verbal interaction. Indeed, since verbal interaction can only exist between individuals, it seems intuitive to focus analyses on inter-individual neural markers, i.e. between-brain neural coupling. To date, however, there is a severe lack of theoretically-driven, testable hypotheses about what between-brain neural coupling actually reflects. In this paper, we develop a testable hypothesis in which between-pair variation in between-brain neural coupling is of key importance. Based on theoretical frameworks and empirical data, we argue that the level of between-brain neural coupling reflects speaker-listener alignment at different levels of linguistic and extra-linguistic representation. We discuss the possibility that between-brain neural coupling could inform us about the highest level of inter-speaker alignment: mutual understanding.

5.1. Introduction

Recent advances in the field of social neuroscience suggest that in order to get at a complete understanding of the different neural processes involved in social interaction, the dynamic interplay between the brains of two interacting individuals needs to be studied (e.g. Hari et al., 2015; Hasson et al., 2012). The inter-individual neural markers of interest are inter-subject correlations in temporal and spatial patterns of brain activity, also known as *between-brain neural coupling* (Stephens, Silbert & Hasson, 2010). Assessing the level of between-brain neural coupling requires measuring brain activity for two (or more) participants involved in a social interaction, a technique called hyperscanning (brain activation is measured for both participants at the same time) or pseudo-hyperscanning (measuring brain activity for both participants in the interaction, but sequentially, one participant at a time). Since the first application of the hyperscanning method in fMRI (Montague et al., 2002), it has been applied to other neuroimaging methods as well (EEG, fNIRS and MEG) and used to investigate different aspects of social interaction (for overviews see Babiloni & Astolfi, 2014; Dumas et al., 2011; Konvalinka & Roepstorff, 2012).

In the current paper, we zoom in on what the multi-brain approach has contributed, and can contribute in the future, to our understanding of verbal interaction. Given the fact that verbal interaction is ubiquitous in our everyday lives, it is surprising that relatively few multi-brain studies have focused on this specific form of social interaction. So far, most multi-brain verbal communication studies have used the hyperscanning method to investigate the spatial and temporal relationship between neural mechanisms which support language production by the speaker and comprehension by the listener (see section 2). Although these studies claim to investigate the neural correlates of verbal information transfer, they generally ignore pair-specific information about the quality of the interaction: whether information transfer was actually successful. However, it has been previously suggested that successful communication or mutual understanding can be operationalized in the form of inter-subject correlations in brain activity (Menenti, Garrod, et al., 2012; Stephens et al., 2010). We argue that the reason this idea has not been investigated in more detail is that although intuitive, it is not backed up by a strong theoretical framework leading to testable hypotheses.

We will discuss a recent theoretical framework (Friston & Frith, 2015a; 2015b) leading to the testable hypothesis that the strength of between-brain neural coupling reflects speaker-listener alignment at multiple representational levels (section 3). In section 4, we consider the possibility that between-brain neural coupling could reflect alignment at the highest representational level possible: the level of the situation model. If so, this would provide us with an inter-personal marker of successful communication. We discuss several possibilities to test this hypothesis before concluding this paper with an outlook on how the hyperscanning method may be used in future research.

5.2. A multi-brain approach to studying the relationship between language comprehension and production

There have been a few studies that have investigated speaker-listener neural coupling during verbal communication (Dikker, Silbert, Hasson, & Zevin, 2014; Jiang et al., 2012; Kuhlen, Allefeld, & Haynes, 2012; Silbert, Honey, Simony, Poeppel, & Hasson, 2014; Stephens et al., 2010). Like two-brain studies on non-verbal communication (Anders, Heinzle, Weiskopf, Ethofer, & Haynes, 2011; Ménoret et al., 2014; Schippers, Roebroeck, Renken, Nanetti, & Keysers, 2010), most of these studies have used the multi-brain approach to investigate 'information flow' from the brain of the sender (the speaker) to the brain of the receiver (the listener). In other words, to what extent is neural activity associated with encoding of information by the sender mirrored in the activity associated with the decoding of that information by the receiver? The reasoning here is as follows: if activity in area X in the brain of the sender is temporally correlated with activity in area X in the brain of the listener (perhaps with a delay), this indicates that area X is associated with encoding as well as decoding of information. More specifically, for verbal communication, such a finding would indicate that the neural infrastructures for language production and comprehension at least in part overlap, opposing the classical Wernicke-Lichtheim-Geschwind model, in which a strict division of labour is proposed. However, speaker-listener correlations in brain activity would be in line with converging evidence from patient data (e.g. Caramazza & Zurif,

1976) and one-brain neuroimaging studies (Menenti et al., 2011; Segaert et al., 2012), which support the view that the same brain regions may support language production as well as comprehension.

In the first two-brain study on verbal communication, Stephens and colleagues (Stephens et al., 2010) recorded a speaker telling an unrehearsed real-life story and played this recording to eleven listeners. Crucially, brain activity was measured with fMRI for both the speaker and listeners. By modelling the expected activity in the listeners' brains based on the speaker's neural activity during speech production, Stephens et al. tested whether the neural activity of the speaker was temporally and spatially coupled to the shared neural activity observed across all listeners. In other words, they tested whether there was overlap in brain areas involved in producing and listening to speech, and whether these activation patterns in the speaker and listener's brains were temporally related to each other (e.g. whether the speaker's brain activity preceded the listener's brain activity). Indeed, Stephens et al. found widespread spatial coupling between brain activity in the speaker and listener, both in areas classically associated with language processing (such as the left superior temporal gyrus and the left inferior frontal gyrus), and in areas that support processes that are generally considered to be extra-linguistic (such as the precuneus and the medial prefrontal cortex). Temporally, for most (but not all) of these areas within the listeners' brains, activity lagged behind the speaker's brain by three to six seconds. Crucially, the spatial and temporal coupling that was found when the speaker and listeners processed the same story largely disappeared when listeners were listening to a Russian speaker, or when the brain activity of the speaker that was used to model the listeners' neural responses was associated with the speaker telling a different story than the story the listeners were listening to. This indicates that between-brain neural coupling does not only depend on producing and hearing the same acoustic signal, but also on the extent to which the signal can be decoded by the listener. If the listener cannot process the linguistic input to extract meaning and structure, the underlying linguistic processes do not match and there will thus not be any coupling in areas necessary for these processes.

Other fMRI studies in which the two-brain approach has been applied to similar verbal information transfer paradigms report similar results (Silbert et al., 2014; Spiegelhalder et al., 2014). In general, these studies report enhanced between-brain neural coupling during one-way communication; when producing or listening to the same verbal information stimulus, the brain activity of the speaker is reflected in the brain of the listener. Together, these studies provide a novel type of evidence in favour of the hypothesis that language production and comprehension depend (at least in part) on the same neural mechanisms. This information is crucial for theories trying to explain behavioural phenomena in dialogue which require close coupling between language production and comprehension processes and/or shared representations at different linguistic and non-linguistic levels (see also: Pickering & Garrod, 2014). One example of such a behavioural phenomenon in dialogue is syntactic priming: hearing a specific sentence structure increases the chance that speakers will use this structure in a subsequent utterance. For this type of behavioural priming to occur from comprehension to production, one must assume some degree of shared representation and/or processing at the level of sentence structure (Menenti, Garrod, et al., 2012).

Most multi-brain verbal interaction studies have thus used speaker-listener between-brain neural coupling to identify neural networks associated with language production as well as language comprehension. These results have been taken as evidence to support theories which propose that a certain degree of overlap in the neural networks underlying language production and comprehension is necessary to explain inter-personal behavioural phenomena in natural conversation, such as priming. However, we would also like to make a critical observation here. By focusing research on identifying brain networks required for language production and comprehension, most of the studies discussed above have reported between-brain neural coupling common for all interaction pairs in their sample. Indeed, by comparing inter-subject correlations in pairs that produce and understand the same communicative signal to the correlations in pairs who are not coupled in this way, one can extract brain areas that are necessary to produce the signal on the one hand, and comprehend it on the other. However, by focusing on what is present across all pairs, we lose pair-specific information about the quality of the interaction, which may vary from pair to pair. In the next section, we will discuss what between-pair variation in speaker-listener neural coupling could tell us about the quality of verbal interaction.

5.3. Between-brain neural coupling as a measure of speaker-listener alignment

So far, we have discussed results of two-brain studies using verbal communication paradigms that have looked at between-brain neural coupling at the group level, identifying brain areas that show reliable inter-subject correlations across all real communication pairs. In this section, we will instead focus on variations in the level of between-brain neural coupling between different sets of communication pairs. More specifically, we hypothesize that between-pair differences in the extent of between-brain neural coupling may be explained by the level of alignment between speaker and listener at multiple levels of linguistic and extra-linguistic representations.

Our hypothesis is largely based on a recent theoretical framework proposed by Friston and Frith (Friston & Frith, 2015a; Friston & Frith, 2015b). As an extension of the more general predictive coding framework, Friston and Frith consider communication in terms of inferences about others. Indeed, predictive coding theory assumes that our brain infers the causes of sensory input to be able to correctly predict upcoming input. The predictive coding framework fits within a shift in cognitive neuroscience away from seeing the brain as a passive filter of information and towards a view of the brain as an active organ that generates predictions about upcoming sensory input. These top-down predictions are compared to representations at lower levels of the hierarchy to form a prediction error: a bottom-up signal reflecting the mismatch between prediction and actual sensory input. Prediction errors can be seen as feedback signals that ensure that the internal or generative model is updated, so that predictions are adapted and prediction errors for future incoming input are minimized.

In the predictive coding framework, the main goal of the brain is to minimize prediction error. According to Friston and Frith, prediction error for the listener in a communicative context would be minimized if they converge on a similar or identical internal or generative model as their partner. Put differently, alignment of these internal models would lead to successful predictions for the listener and thus facilitated communication. Crucially, Friston and Frith suggest that when the listener can correctly predict what the speaker will say next, their neural states will show what they call *generalized synchrony*. Friston and Frith explain generalized synchrony as knowing the neural state of one brain in a pair by knowing the neural state of the other brain in that pair. Indeed, this is very similar to the definition of between-brain neural coupling that we have used above: inter-subject correlations in brain activity.

But how is it that correctly predicting what the speaker says leads to coupling (generalized synchrony) between brain activity of speaker and listener? This would only be possible if speaking and listening are both driven by the same underlying processes. Indeed, this is what is proposed in the predictive coding framework: the predictions that are generated by any individual cannot only be tested against external input; they can also be enacted. According to Friston and Frith, action and perception (language production and comprehension) are two sides of the same coin. The predictions generated are amodal in nature and not specific for comprehension or production only. Therefore, when the listener has correctly inferred the speaker's generative model, their predictions will be similar, which is in turn reflected in generalized synchrony or between-brain neural coupling.

Generalized synchrony is a ubiquitous phenomenon in loosely coupled dynamical systems. In the context of communication and predictive coding, it attains a special status. This is because communication in the sense of aligning internal representations (i.e., a dialogue) requires turn taking and the reciprocal augmentation and attenuation of expressive versus receptive processes. If I can use my same predictive machinery to predict (and confirm) what I am listening to, as well as to provide motor predictions that allow me to articulate a narrative, then if we are in true alignment and are 'on the same page', then it does not matter whether you or I are speaking – because we should be hearing the same thing. This form of generalized synchrony can be regarded as the dynamical homologue of alignment in communication, which rests upon an amodal representation of a narrative (that can be used for speaking or listening respectively).

This account of communication thus provides us with a theoretical backdrop about the mechanisms that lead to between-brain neural coupling. Furthermore, it makes a specific causal prediction: the extent to which brain activity of speaker and listener are coupled should be modulated by the extent to which the listener has correctly inferred the generative model of the speaker, and thus can predict upcoming input. Between-brain neural coupling can therefore be operationalized as a measure of alignment of the speaker and listener's generative models. However, what remains unclear is what would be represented in such a dynamic generative model, and at what level predictions are made. Based on behavioural research, others have proposed that for a hierarchical system like language, interlocutors align at many different representational levels (Garrod & Pickering, 2009; Pickering & Garrod, 2004), ranging from very low-level acoustic features such as speech rate (Webb, 1969) or accent (Giles & Powesland, 1975), to higher linguistic levels such as the lexical (Brennan & Clark, 1996) and syntactic (Branigan et al., 2000) levels, all with the ultimate goal to align extra-linguistic levels such as the representation of the situation under discussion (i.e. situation model). We hypothesize that the generative model entails all these levels, but interlocutors may be more or less aligned at different levels of the hierarchy.

In line with this hypothesis, we predict that the level of representation on which listeners are aligned with their partner should be reflected in the spatial pattern of between-brain neural coupling. For example, if listeners have aligned their representations with the speaker's at the syntactic level, this should minimally be reflected by neural coupling in cortical areas associated with syntactic processing. Although this hypothesis would definitely require further testing, there is one two-brain study that provides initial evidence. Above, based on the theoretical framework by Friston and Frith (Friston & Frith, 2015a; Friston & Frith 2015b), we hypothesized that speaker-listener neural coupling reflects alignment of their generative models, leading to similar predictions about upcoming information. A study by Dikker and colleagues (Dikker et al., 2014) measured brain activation (fMRI BOLD response) for one speaker and nine listeners. The speaker described pictures depicting events that could be described with a sentence containing a transitive verb. The lexical-semantic content of the speaker's sentences was classified as predictable or unpredictable, based on the degree to which the items in the depicted scene predicted for specific lexical choices. Predictability was assessed in a separate behavioural experiment. A picture was classified as highly predictable when there was high inter-speaker agreement (>85%) in the lexical-semantic content of the sentences used to describe a picture (e.g. a penguin hugging a star: more than 85% of the speakers described this scene with "the penguin is hugging the star"). For low-predictability items, inter-speaker agreement was low (<35%, e.g. the guitar is boiling/cooking/stirring the wheel/tire/bike). It is important to note that the predictability of syntactic structure did not vary: the speaker always used simple declarative sentences. The speaker's descriptions were then presented to the listeners. Crucially, Dikker et al. report stronger speaker-listener coupling for predictable relative to unpredictable descriptions in the left posterior superior temporal gyrus, which is, according to them, associated with lexical-semantic processing. This study provides initial evidence that speaker-listener neural coupling is influenced by the extent to which the listener is able to predict the speaker's utterance, as would be predicted by our hypothesis. Furthermore, when manipulating predictability at the lexical-semantic level, this leads to variations in coupling in brain areas associated with lexical-semantic processing.

It would be very interesting if we could extend and test this idea to higher levels of representational alignment. If so, between-brain neural coupling might be an interpersonal neural marker for the ultimate goal of communication: mutual understanding, or alignment at the level of the situation model. We will elaborate on this idea in section 4 below.

5.4. Towards an inter-personal marker of mutual understanding?

An initial attempt to investigate the relationship between inter-subject correlations in brain activity and mutual understanding was done by Stephens et al. (Stephens et al., 2010). As explained in section 2 of this paper, there was one speaker telling a story, and eleven listeners who listened to that story in the MRI scanner. What was not mentioned in section 2 was that after hearing the story, listeners were asked to retell the story that they heard with as much detail as possible. Based on this retelling, Stephens et al. calculated for each listener to what extent the story told by the speaker was successfully communicated (i.e. speaker-listener alignment at the level of the situation model). Successful communication was thus defined as the level of specificity with which listeners could retell the story. This measure was then used as a factor to explain variance in the extent (i.e. the number of brain areas in which significant coupling was found) that the listener's brain activity reflected the speaker's brain activity. Stephens et al. found a positive relationship between their measure of communicative success and the extent of speaker-listener between-brain coupling, which they argue to be evidence in favour of the idea that between-brain neural coupling reflects alignment at the level of the situation model.

However, it should be clear that this study cannot provide conclusive evidence that variations in interpersonal correlations in brain activity reflect variations in alignment at the level of the situation model. Next to the fact that a replication of these results would be warranted, one could question whether this design is best to address the question. If alignment at the level of the situation model is reflected in between-brain neural coupling, we would expect that this type of alignment is independent of the communicative signal. The design used by Stephens et al. does not disentangle neural coupling due to alignment at low levels of linguistic processing, which would depend on the actual communicative signal, from higher, abstract levels at the level of the situation model. Indeed, the same communicative intent could be signalled in many different ways. To extract between-brain coupling due to alignment at the level of situation models, one might compare between-brain coupling for speaker-listener pairs in which the speakers always convey the same communicative intent (e.g. they want to describe an event), but vary in the way they describe that event.

An additional important problem with the study by Stephens and colleagues is that listeners were asked to retell the story that they had just heard. This assumes that alignment of generative models is a static end-state of a communicative process. However, in their theoretical framework, Friston and Frith assume that the generative model driving predictions, and therefore between-brain coupling, is dynamic and changes over the course of the interaction. A similar idea has been proposed by Stolk and colleagues (Stolk, Verhagen, & Toni, 2016). In their *conceptual alignment* framework, they argue that as the interaction unfolds, communicators continuously update their conceptual spaces (the conceptualization of which we believe to be similar to our earlier conceptualization of a generative model at the level of the situation model). Based on this idea, they predict that not only should producing and interpreting a communicative signal lead to inter-communicator between-brain neural coupling, the temporal dynamics of this shared pattern of neural activity should reflect communicators' *adjustments* of their shared conceptual spaces (i.e. situation model), which would be crucial for mutual understanding.

Interestingly, they provide support for this hypothesis in a non-verbal communicative hyperscanning fMRI experiment (Stolk et al., 2014). In this experiment, participant pairs were presented with novel and known communicative problems. Crucially, for the novel communicative problems, there was no previously established solution: participants had to coordinate and mutually adjust their situation models or conceptual spaces. Interestingly, Stolk et al. report stronger between-brain neural coupling (in right superior temporal gyrus) when both participants had to adjust their situation model relative to when no such adjustments were necessary. Although Stolk et al. made use of a non-verbal communication paradigm, this may be extended to a verbal communication paradigm in which interlocutors do or do not have to mutually adjust their generative model.

When thinking about between-brain neural coupling as a potential marker for mutual understanding, mutual understanding should not be conceptualized as a static end-state that is the result of successful communication. Rather, it has been argued that speaker-listener neural coupling reflects a continuous process of between-participant alignment of their generative models (Friston & Frith, 2015a; Friston & Frith, 2015b; Stolk et al., 2016), which, in turn, would be crucial for communication to be successful.

5.5. Discussion

Recently, it has been argued that to study the neural basis of social interaction, which necessarily only exists between individuals, one should not study within-individual brain activity but instead focus on the dynamical interplay between the brains of individuals in interaction. Although this idea is intuitively appealing, it remains unclear what we can learn from such a two-brain approach to interaction: what is reflected in between-brain neural coupling? In the current paper, we zoomed in on the questions that can be addressed by applying the two-brain approach to the study of the neural basis of verbal communication, linking theoretically-motivated frameworks to testable hypotheses and existing empirical data.

In section 2, we discussed how the hyperscanning method has been used to identify brain networks that are associated with language production as well as language comprehension. Indeed, if activity in area X in the brain of the sender is temporally correlated with activity in area X in the brain of the listener, this indicates that area X is associated with encoding as well as decoding of information. Although most (verbal) communication studies have applied this reasoning to study the neural correlates of information transfer, we argued that by focusing on what areas show consistent coupling across all speaker-listener pairs, we ignore possibly valuable information that is represented in between-pair variation at the level of between-brain neural coupling. Therefore, in section 3, we discussed a theoretical framework (Friston & Frith, 2015a; Friston & Frith, 2015b) and formulated the hypothesis that the level of between-brain alignment depends on how aligned listeners are with a speaker, at different levels of linguistic and extra-linguistic representation. This hypothesis led to the intuitively appealing idea that between-brain neural coupling could be an inter-personal neural marker for the highest level of alignment: alignment at the level of the situation model, or mutual understanding. In section 4, we argued that to address this question, alignment at this level should not be conceptualized as a static end-state of communication, but rather as a dynamic and continuous process, which may indeed be reflected in between-brain neural coupling.

Before concluding, there is one last issue we want to address. Almost all two-brain studies on verbal communication that have been discussed so far in this paper have considered communication as a unidirectional process which can be described as transferring information from speaker to listener. In line with this idea, experimental paradigms include two participants, where one is always the speaker (or sender) and one is always the listener (or receiver). In other words, the set-up resembles a monologue (i.e. giving a speech or a lecture) rather than a dialogue, in which participants take turns speaking and listening. Whereas the monologue set-up suffices to investigate whether there is a shared neural circuitry underlying language production and comprehension, it is not the ideal set-up to study inter-personal neural markers of between-subject alignment. Indeed, we need to consider the fact that alignment of situation models is often the result of a joint process: interlocutors build up meaning together. The Interactive Alignment theory (Pickering & Garrod, 2004), for example, suggests that alignment of situation models is facilitated when interlocutors' align their behavioural output (e.g. on the lexical or syntactic level). If between-brain neural coupling is associated with alignment of situation models, an interesting question may be whether aligning behaviour results in stronger neural coupling between interlocutors. Initial evidence that supports this idea comes from a study by Jiang et al. (Jiang et al., 2012), who actually did include a dialogue condition in their two-brain study. Using fNIRS hyperscanning, Jiang et al. investigated neural coupling between interlocutors in dialogue and monologue contexts. They found a significant increase in between-brain coupling in the left inferior frontal cortex for face-to-face dialogue, but not for monologue, and attribute their result to the fact that in face-to-face dialogue, there was alignment on different levels of (verbal) behaviour and turn-taking, which was not the case for monologue. Although the study by Jiang et al. was not designed to test theoretically-driven, causal predictions like the predictions proposed in this paper, at the very least, their study proves the feasibility of measuring between-brain neural coupling in an interactive, bidirectional setting which resembles natural interaction in dialogue. Together with the causal predictions that have been formulated in the current paper, we argue that the time has come to move to a two-brain approach of verbal interaction, rather than a two-brain approach of one-way verbal communication.

5.6. Conclusion

In this paper, we have addressed the question: what can we learn from a two-brain approach to verbal communication? Although the idea is intuitively appealing, to date, there has been a severe lack of theoretically-driven hypotheses about what between-brain neural coupling actually reflects. We believe that such hypotheses are necessary for the field to move forward. By linking theoretically-motivated frameworks to existing empirical data, we have identified testable hypotheses that may be explored in future research.

CHAPTER 6

fMRI inter-subject correlations as neural markers of successful communication

Adapted from: Schoot, L., Stolk A., Hagoort, P., Garrod, S., Segaert, K. & Menenti, L. (in preparation). fMRI inter-subject correlations as neural markers of successful communication.

Abstract

Communication is successful when interlocutors have aligned their mental representations of the situation under discussion. In the current study, we let speakers describe an abstract map of a zoo (a 6x6 or 8x8 grid containing circular, squared and triangular animal enclosures), and present the recording of that description to a listener while we measure neural activation (fMRI) for speaker and listener. With this task, the speaker is communicating a well-characterized situation model to a listener and we can quantify the level of communicative success as the performance of the listener in a post-hoc behavioural task. During communication, we measure inter-subject correlations between the temporal pattern of brain activity of speaker and listener. The reported inter-subject correlations reflect brain regions necessary for describing and interpreting the situation model. Moreover, we show that the degree to which communication was successful (i.e. situation models were aligned) is reflected in the degree of inter-subject correlations in brain regions associated with processing crucial aspects of the content of the situation model that is being described.

6.1. Introduction

Imagine that you are looking for a hotel in an unfamiliar city. After ten minutes spent zigzagging through the city's streets, but not getting anywhere closer to the hotel, you decide to ask a passerby. Luckily, he knows where the hotel is: '*straight ahead, take the third right, second left and then first right again*.' A few minutes and two traffic lights later, you've taken the third right and are getting into an argument with your friend: was it the second left, first right, was it second right, first left, or was it first left, second right?

We use language to communicate. If all goes well, at the end of a conversation language has helped in transferring information from one brain to the other (and vice versa). Others have put this in terms of interlocutors aligning their *situation models:* a mental representation of the situation under discussion (Pickering & Garrod, 2004; Zwaan & Radvansky, 1998). If communication was successful, interlocutors' situation models have been aligned and they have achieved mutual understanding of the situation under discussion.

Recently, it has been suggested that a full understanding of the neural mechanisms underlying successful communication, which can only exist *between* individuals, requires a shift in focus away from studying brain activation patterns within one individual, and towards the identification of inter-individual neural markers (Hari et al., 2015; Hasson et al., 2012). These inter-individual neural markers are inter-subject correlations in temporal and spatial patterns of brain activity, or between-brain neural coupling. Indeed, if one assumes that overlap of mental states is reflected in overlap in neural states, a straightforward prediction is that the more successful communication is (i.e. mutual understanding, or, alignment of situation models) the more brain activity between the participants involved in the exchange should correlate (Menenti et al., 2012; Schoot et al. 2016; Stephens et al., 2010; Stolk, 2014).

To test whether inter-subject correlations in temporal and spatial patterns of brain activity reflect speaker-listener alignment, one needs to measure brain activity for both participants in the interaction. Brain activity may be measured for speaker and listener at the same time, i.e. during real-time communication (the true hyperscanning approach; Montague et al., 2002), or sequentially, i.e. the first participant's speech is recorded and that recording is presented to the listener at a later point in time (pseudo-hyperscanning). Since the aim of both set-ups is to relate the measured neural response of the speaker to the response of the listener, we will not differentiate between true hyperscanning and pseudo-hyperscanning methods. In what follows, we will use the term *multi-brain approach*, which covers both experimental methods. Although we will focus our attention on multi-brain studies employing verbal communication paradigms (Dikker et al., 2014; Jiang et al., 2012; Kuhlen et al., 2012; Silbert et al., 2014; Stephens et al., 2010), we would like to note here that the multi-brain approach has been used to study various types and aspects of social interaction (for overviews see Babiloni and Astolfi, 2014; Dumas et al., 2011; Konvalinka and Roepstorff, 2012).

Stephens et al. were the first to measure inter-subject correlations for speaker-listener pairs during verbal communication (Stephens et al., 2010). Using fMRI, Stephens et al. measured neural activity for one speaker while this speaker told an unrehearsed real-life story. The story was recorded and later played to eleven individually tested listeners, while their neural activity was measured in the MRI scanner. By relating the neural response of the speaker telling a story to the shared neural response across all listeners hearing that story, Stephens et al. were able to test whether there were brain regions in which neural activity (as measured by the BOLD response) was temporally coupled between speaker and listeners. Their results showed an extensive neural network that was involved in language production for the speakers as well as language comprehension for the listeners. This network included core language areas (e.g. the left superior temporal gyrus and the left inferior frontal gyrus) as well as brain regions that are not generally considered to be necessary for core linguistic processing (e.g. the precuneus and the medial prefrontal cortex). The analysis reported by Stephens et al. furthermore allowed for a dissociation between regions in which listener's BOLD response was synchronous to the speaker's and regions in which listener's response preceded or followed the speaker's neural response. For most (but not all) regions for which inter-subject correlations were reported, listener's activity was delayed compared to the speaker's activity (3-6 seconds). As a control, Stephens et al. report that most of the regions for which inter-subject correlations was reported, were not significantly coupled when the neural response of the listener was related to the response of a speaker telling a different story (i.e. no overlap in the signal that was produced by the speaker and perceived by the listener). Additionally, when inter-subject correlations were calculated using the BOLD responses of speaker-listener pairs where the listeners were presented with the story that the speaker produced, but in a language the listener did not understand, inter-subject correlations disappeared. This indicates that the extent of speaker-listener neural coupling depends on the ability of the listener to decode the message conveyed by the speaker.

Since the publication of these results in 2010, similar results have been reported by the same group (Silbert et al., 2014). Instead of correlating the time course of one speaker to the average activation pattern of multiple listeners, Silbert et al. performed a novel time-warping analysis to create an average BOLD time-course across one speaker that tells the same story multiple times (the same speaker memorized the story produced in the Stephens et al. study). Silbert et al. do not only report intra-subject correlations in BOLD fluctuations between the speaker's multiple retellings of the same story, but also inter-subject correlations between the average BOLD time-course of the speaker and the average time-course of the listeners. Again, significant inter-subject correlations are reported for brain regions considered to be involved in core linguistic processes, as well as so-called 'extra-linguistic' processing areas, including the precuneus and the medial frontal cortex.

Inter-subject correlations in the neural activity of a speaker and a listener who are behaviorally coupled by producing and understanding the same linguistic signal are interesting for at least two reasons. First of all, temporal cross-correlations in neural activity of speaker and listener provide further evidence against models of language processing that propose a strict division of labor of the neural mechanisms underlying language production and comprehension. If fluctuations in neural activity in area X in the brain of the speaker are temporally correlated with fluctuations in activity in the corresponding area in the brain of the listener, this indicates that area X is associated with encoding as well as decoding of information, i.e. with language production as well as language comprehension.

The existence of inter-subject (speaker-listener) correlations in brain activity is in line with evidence from patient data (e.g. Caramazza and Zurif, 1976) and neuroimaging studies investigating the neural mechanisms of language production and comprehension with a one-brain approach (Awad, Warren, Scott, Turkheimer, Federico & Wise, 2007; Menenti et al., 2011; Segaert et al., 2012). Together, these findings support the view that the brain regions underlying language production and comprehension at least partly overlap.

Second, the fact that speaker-listener between-brain neural coupling exists beyond core language areas is a first indication that inter-subject correlations in brain activity of speaker and listener might reflect alignment of that speaker-listener at higher representational levels: i.e. situation model alignment or mutual understanding (Pickering & Garrod, 2014). We believe that this is where the multi-brain approach could make a unique contribution to our understanding of the neural mechanisms underlying (verbal) communication: if successful communication necessarily requires two brains, should we not look for an inter-individual marker of communicative success?

However, to truly say that coupling in regions associated with higher-order cognitive processing reflects mutual understanding of the situation under discussion (i.e. alignment of situation models), coupling strength of a speaker-listener pair should be related to the degree of alignment of that pair, or, in other words, to how successful communication was. This requires a shift away from looking at group averages and focusing on individual (pair-specific) differences. So far, only one study has investigated the relationship between speaker-listener alignment and inter-subject correlations in neural activity. In the study by Stephens et al., successful communication was assessed based on the listener's performance on a behavioral task after hearing the story in the fMRI scanner. The listeners were asked to retell the story they heard with as much detail as possible. The measure of communicative success thus reflected the level of detail with which the listener could reproduce the story that they heard. This performance measure positively predicted the extent of coupling between neural activity of the speaker and that listener. The extent of coupling was here defined as the number of regions in which significant inter-subject correlations were found. Stephens et al thus found that the better the listener's performance and thus the more successful communication, the more brain regions for which significant inter-subject correlations were reported. In the current study, we elaborate on this idea. However, we hypothesize that alignment of situation models does not necessarily lead to more areas for which correlation is reported, but stronger correlations in the areas associated with processing the content of a situation model (Schoot, Hagoort, & Segaert, 2016).

The goal of the current study is twofold. First, we wish to replicate previous findings that show that inter-subject correlations between brain activity of speaker and listener can be found during communication. To some extent, our experimental design is similar to the designs used by Stephens et al. (2010) and Silbert et al. (2014). Like them, we also make use of a pseudo-hyperscanning paradigm, in which we let speakers tell a story first, and later play the recording of this story to a listener. However, our paradigm is novel in the sense that each speaker-listener pair is unique: instead of letting multiple listeners listen to the same story produced by one speaker, in our study, each speaker conveys a unique situation model. This way, we address the problem that in the previous studies, it is unclear to what extent the results are specific to this one particular stimulus, or to what aspect of the stimulus they were due. This is especially problematic when we want to look at the relationship between inter-subject correlations in fMRI BOLD response and speaker-listener alignment at high levels of representations. By letting each speaker describe a unique stimulus, but precisely specifying the content of that stimulus, we can be sure that our results are not specific to one particular instance of verbal communication, but rather apply to what is common among pairs.

Our second aim was to explore whether inter-subject correlations in brain activity can tell us more than whether there is overlap in brain regions responsible for language production and comprehension. Indeed, we explore whether speaker-listener correlations in brain activity can reflect communicative success: situation model alignment. To this end, we have to look at between-pair variation in the strength of speaker-listener correlations, instead of focusing on averages based on all pairs. We predict a higher degree of speaker-listener alignment will relate to stronger correlations in brain regions necessary to build up a representation of the situation model.

6.2. Method

6.2.1. Participants

All participants were right handed native English speakers with no history of neurological or language disorders. They were attending or had attended university education and were recruited at the University of Glasgow. Participants received a monetary reward or course credit for their participation. The analyses reported below are based on data from 24 speaker-listener pairs. A pair is defined as a unique combination of speaker and listener, in which the listener is presented with a description of that speaker. All speakers described two zoo types (one easy and one difficult, see section 2.2) and every listener was presented with two descriptions (one easy and one difficult). Listeners did not hear two descriptions by the same speaker. Due to the fact that there were more listeners than speakers, some listeners were presented with the same description. However, no two listeners heard the same combination of descriptions in easy and difficult condition. Thirteen speakers and 18 listeners completed the experiment. Due to severe spiking artifacts in the fMRI data, we excluded three speakers from further analyses. We thus analyzed the data for 10 speakers (20 recordings). Four recordings were presented to 2 listeners each, so there were 24 unique communication pairs included in the analysis.

6.2.2. Stimuli and Design

Speakers memorized schematic maps of two zoos, one easy and one difficult. Both maps consisted of a square grid, with enclosures that were circular, triangular, or square (all three shapes were present in each map), and each enclosure contained a different type of animal (see Fig. 1). The easy map was laid out on a 6x6 grid and contained five enclosures; the difficult map was laid on an 8x8 grid and contained seven enclosures. All individual maps were different and were randomly constructed given the constraints above: a random sample of grid location was taken, the shape of the enclosure at each location was randomly determined, and the animal contained in each enclosure was again randomly sampled.

Listeners heard the speakers' descriptions. These descriptions were recorded with noise cancellation inside the MRI scanner. Where necessary we applied further filtering of noise, using noise-filtering algorithms included in Adobe

Soundbooth. The recordings lasted four minutes. Descriptions varied widely in used strategy, speech rate, variability in syntactic structures used, and the extent to which the audience was taken into consideration. Each speaker's description was played to at least one listener. The two descriptions of a speaker were played to different listeners, meaning that every listener heard descriptions of two different speakers.

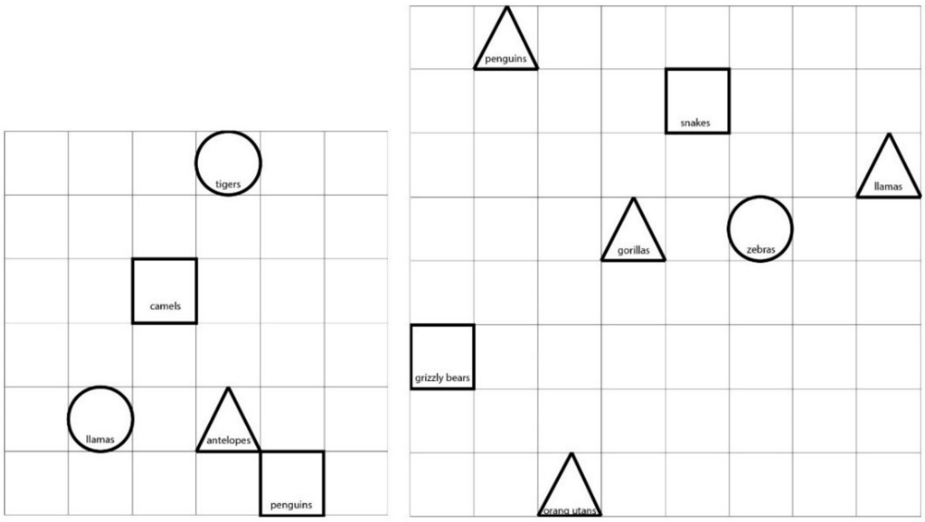

Figure 6.1. Example of the zoo-maps presented to the speaker. Left: Easy map (6x6 grid, 5 animal-enclosure combinations) Right: Difficult map (8x8 map, 7 animal-enclosure combinations).

6.2.3. Task and Procedure

Stimuli were presented using the PsychToolbox extension in Matlab (Brainard, 1997; Pelli, 1997).

<u>Speakers</u> memorized maps of two zoos, one easy and one difficult. The maps were memorized separately, one before each run of the fMRI experiment. The participants' task was to memorize each well enough to "be able to describe it from memory to someone else who then had to redraw the map based on their description". The experimenter therefore stressed the communicative aspect of the task. Speakers got as much time as they liked to memorize the map. They were encouraged to test their knowledge with empty sheets on which to redraw the map. When they were satisfied they knew the map, they entered the MRI scanner. Their first task in the scanner was to produce a description of the map, "in such a way that

someone else could redraw the map". They had four minutes to do this, and were instructed to keep speaking as long as the run lasted, "as the listener would need to hear the information several times, perhaps described in different ways".

The experiment consisted of two MRI runs with a break in between. Each MRI run consisted of three scans. The first was always a zoo map (the order of easy and difficult maps was counterbalanced). The other four scans were the following: a resting state scan of four minutes, a story presented paragraph by paragraph, to be read aloud during one run and silently during another (an abbreviated version of Rudyard Kipling's *How the Elephant got its trunk*), an attempt to sing a song (*Ten green bottles*) to a metronome. The story and song are not considered here. In the break between scans, participants memorized the second zoo map. All descriptions were recorded using an Optoacoustics FOMRI-III microphone. This uses built-in digital signal processing algorithms to filter out the scanner noise from the recording.

Listeners heard descriptions of two zoos, the descriptions produced by the speakers in the MRI scanner. The listeners' fMRI experiment consisted of one run, with four scans. The first and last were each a description of a zoo map, one easy and one difficult (the order of easy and difficult maps was counterbalanced). Immediately after each description, the participants saw a grid of the correct size, and had to reproduce the map using a Current Designs fiber-optic trackball mouse. To reproduce the map, they had to select the correct location of each enclosure, choose whether it was a triangle, a square or a circle, and select the correct animal species from a list of 36. Between the two zoo descriptions, the listeners had a resting state scan of four minutes, and a scan in which they heard a story, the story read out loud by the speakers (not considered in the analyses presented below).

6.2.4. Data acquisition

Data acquisition took place at the University of Glasgow, in a 3-T Siemens Magnetom Tim-Trio magnetic resonance imaging scanner using a 32-channel surface coil. To acquire functional data, we used parallel-acquired inhomogeneity-desensitized fMRI (Poser et al., 2006). In this multiecho-planar imaging sequence, images are acquired at multiple echo times following a single excitation. Accelerated parallel imaging helps to reduce motion and susceptibility artifacts in the data and thus is a good method to acquire data when participants are speaking in the scanner (Menenti et al., 2011; Menenti, Segaert, et al., 2012; Segaert et al., 2012).

For the functional scans, the TR was 1830 ms and each volume consisted of 31 slices of 3 mm thickness with a slice-gap of 17 % of the slice thickness. The voxel size was 3.5 x 3.5 x 3 mm and the field of view was 1344. Functional scans were acquired at multiple TEs following a single excitation (TE1 at 9.4 ms, TE2 at 17.21 ms, TE3 at 25.02 ms, TE4 at 32.83 ms, and TE5 at 40.46 ms) so that there was a broadened T2* coverage. The number of slices did not allow for complete full brain coverage in most participants. The experimenter made sure that the frontal and temporal lobes, where activations of interest were expected, were always included. This meant that in many participants, data from the top of the head was not acquired.

A whole-brain high-resolution structural T1-weigthed MPRAGE sequence was performed to characterize participants' anatomy (TR = 1900 ms, TE = 2.52 ms, voxel size of 1 mm^3, FOV = 256), accelerated with GRAPPA parallel imaging (Griswold et al., 2002).

6.2.5. Analysis

6.2.5.1. Behavioral data analysis

Listeners listened to the speaker's description of a zoo map and were then asked to reproduce this map. We scored these reproductions to get at a measure of communicative success. For every animal-shape-location combination, the listener could get three points, one for each of the aspects of this combination (animal, enclosure shape and location on the map). For the easy zoo, a total of 15 points would be a perfect score (5 animal-shape-location combinations). For the difficult zoo, perfect score is 21 points (7 animal-shape-location combinations). To be able to compare between the two conditions, all scores were converted to a percentage.

This behavioral score (listener performance) was used as a covariate to investigate the inter-subject neural correlates of communicative success.

6.2.5.2. fMRI data analysis: Preprocessing

fMRI data were preprocessed using SPM8 (Statistical Parametric Mapping; www.fil.ion.ucl.ac.uk/spm) unless otherwise stated. The five echoes of the images were realigned to correct for motion artifacts (realignment parameters were estimated for one echo and then copied to all other echoes). Next, the five echoes were combined into one image using a method designed to filter task-correlated motion out of the signal in a customized SPM5 script (Buur, 2009). First, echo two to five were combined using a weighting vector dependent on the measured differential contrast to noise ratio. The time course of an image acquired at a very short echo time (i.e. TE1) was used as a voxel wise regressor in a linear regression for the combined image of TE2, TE3, TE4 and TE5. Weighting of echoes was calculated based on 30 volumes acquired before the actual experiment started. The resulting images were co-registered to the participant's anatomical scan (after prior co-registration of both image types to their respective Montreal Neurological Institute (MNI) templates). Each anatomical image was segmented into three different tissue compartments (grey matter, white matter and cerebral spinal fluid). Functional images were normalized to MNI space using these segmentation parameters and spatially smoothed using an isotropic 8mm FWHM Gaussian kernel. As a final step, the functional images were filtered using a customized Matlab script (Hermans et al., 2011). Filtering consisted of the removal of low frequency confounds (.01 Hz cut-off discrete cosine transform high pass filter) and six movement parameters from all participants' time series. Next, a grey-matter mask with a probability threshold of .45 was applied to the functional data. This way, we could extract each participant's global grey matter signal, i.e., the mean BOLD signal time course across all grey matter voxels of a single participant, and regress this out of each voxel's time course.

6.2.5.3. fMRI data analysis: Inter-subject correlation maps

Inter-subject correlation maps were created by cross-correlating subject-specific, standardized, filtered time series for each voxel, for each speaker-listener pair. Correlation coefficients were then normalized using a z-transformation. We created inter-subject correlation maps for all pairs (speaker-listener pairs for which the description of the speaker was played to the listener in that pair). For all pairs, we also created inter-subject correlation maps of their time-series in the rest condition (time series of same length, but no language production and/or comprehension). Lastly, for all pairs, we created two additional inter-subject correlation maps to account for a possible delay in activation for the listener: one map with 1 TR delay for the listener and one map with 2 TR delay for the listener.

6.2.5.4. fMRI data analysis: Group-level statistics

Whole brain analyses were performed in SPM8, using the pair-specific speaker-listener correlation maps as input. Cluster size was used as the test statistic and only clusters significant at $p < 0.05$ FWE corrected are reported. Local maxima are also reported for all clusters with their respective Z values.

The first set of analyses reported below was aimed at identifying brain areas that are necessary for language production and language comprehension. We therefore focus on average fMRI inter-subject correlations across all speaker-listener pairs. First, we ran a one-sample t-test with listener performance as covariate. A second analysis was run to identify brain areas in which between-brain neural coupling is stronger during communication than during rest (again, on average across all pairs). This model included within-pairs factor *Task Type*: inter-subject correlation maps for pairs during the communication task (describe / listen to the description of a zoo map) were compared to maps of the same pairs during Rest (participants had no task). This analysis will enable us to exclude the possibility that any between-brain coupling is due to participants both hearing the noise of the scanner, since scanner noise is present during both tasks. The two whole brain analyses described above were performed using speaker-listener correlation maps that were based on activation that was synchronous in time between speakers and listeners ($T_{listener} = T_{speaker}$). The last whole brain analysis was ran to investigate whether there were areas in which speaker-listener coupling was not synchronous. Indeed, it is likely that some activation in the listener (associated with language comprehension processes) is delayed compared to the speaker ($T_{listener} = T_{speaker} + x$). We compared inter-subject correlation maps of real pairs that were synchronous in time with maps which were based on a 1TR delay in activation pattern for the listener and maps that were based on a 2TR delay for the listener. This was done in a repeated measures ANOVA with one factor with 3 levels: Listener Delay (no delay, 1TR delay and 2TR delay). In addition to the whole-brain analyses, we performed an ROI analysis to look at core language processing areas with more sensitivity. We based our ROIs on coordinates of a previous paper (Menenti, Gierhan, Segaert & Hagoort, 2011) and used Marsbar (http://marsbar.sourceforge.net/) to extract the data (10 mm sphere ROIs).

Next, we moved away from group averages and focused on pair-specific differences in inter-subject correlations. We performed a whole brain analysis to identify brain regions in which the strength of speaker-listener correlations is predicted by speaker-listener alignment (approximated by the listener's performance score on the behavioural task in which they had to recreate the described zoo map).

6.3. Results

6.3.1. An inter-subject correlation approach to reveal brain regions common to language production and comprehension

We first report analyses aimed at identifying brain regions involved in language production (here: describing a zoo map) and language comprehension (inferring the zoo map that is described by the speaker). Our rationale is as follows: if over time, fluctuations in the measured BOLD response in region X in the brain of the speaker are correlated to BOLD fluctuations in the same region in the brain of the listener, it means that this region is involved in the production (at any point in the process, from formulating the message to speech production) and comprehension (from speech perception to interpreting the underlying message) of language. We thus aim to identify brain regions that, on the group level, show significant correlations between fluctuations in the BOLD response of the speaker and in the BOLD response of the listener, i.e. fMRI inter-subject correlations. The analyses reported in this section focus on inter-subject correlations averaged across all speaker-listener pairs, using a GLM approach.

6.3.1.1. Inter-subject correlations in bilateral superior temporal cortex and the left inferior parietal cortex are associated with the production and comprehension of a description of a zoo map

We added pair-specific inter-subject correlation maps into a whole-brain one-sample t-test (with listener performance as a covariate to account for inter-subject variation in communicative success). This analysis showed significant inter-subject correlations for speaker-listener pairs in the left and right superior temporal cortex and the left inferior parietal cortex (Table 6.1, Figure 6.2). However, since there is no explicit baseline condition in this analysis, these correlations (especially in the superior temporal cortex, associated with auditory processing) may be driven by BOLD fluctuations associated with language processing by the speaker and listener, or, alternatively, they may be driven by coincidental similarities in auditory processing of non-linguistic sounds such as MRI scanner noise.

Table 6.1. Results one sample t-test with behavioral performance of the listener as a covariate.

		Global & Local maxima			Cluster-level		Voxel-level
Anatomical label	BA	X	Y	Z	K	P_{FWE}	*Z*
R Superior Temporal	22	64	-18	8	331	<0.001	4.41
R Superior Temporal	22	64	-12	0			4.32
R Superior Temporal	48	64	-2	0			4.40
L Superior Temporal	22	-60	-12	4	82	<0.005	4.09
L Superior Temporal	48	-50	-18	4			3.88
L Inferior Parietal	7	-26	-48	48	105	< 0.001	4.54
L Inferior Parietal	40	-28	-48	40			4.27
L Inferior Parietal	40	-32	-40	42			3.90

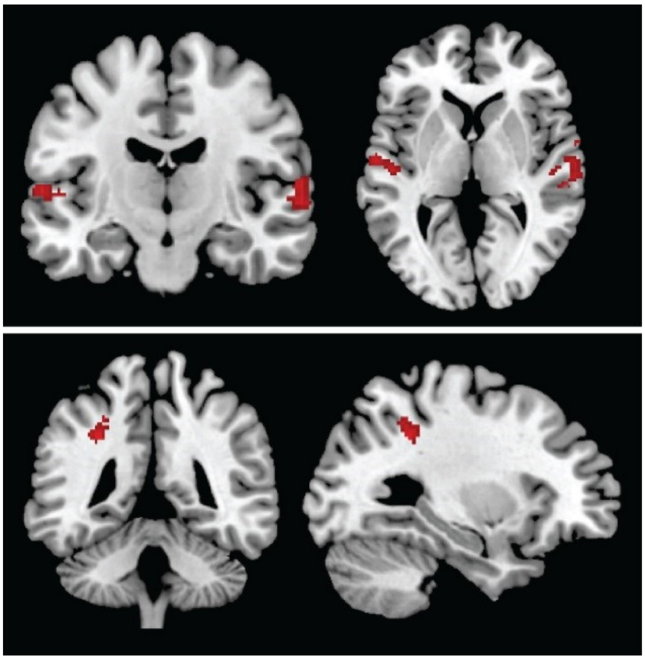

Figure 6.2. Results one-sample t-test: Increased inter-subject correlations between BOLD signal of speaker and listener. Top panel: bilateral superior temporal cortex (MNI coordinates: 64, -18, 8; and -60, -14, 6). Coronal section on the left (left is left) and horizontal section on the right. Bottom panel: left inferior parietal lobe (MNI coordinates: -26 -48 48). Coronal section is on the left, and a sagittal section on the right (right is front of the brain).

6.3.1.2. Inter-subject correlations in bilateral superior temporal cortex are associated with speech processing, rather than similarities in auditory noise

Next we aimed to isolate inter-subject correlations associated with processing speech, but not other sounds. To this end, we ran a whole brain analysis in which we compared the inter-subject correlation maps of speaker-listener pairs during communication (producing or hearing speech) with the maps of the same pairs during rest (i.e. we measured BOLD activity for an equally long period during which participants were not speaking/listening). We found significantly stronger neural coupling in bilateral auditory cortices during communication than during rest, indicating that BOLD fluctuations in this region were driven by producing and/or hearing speech, and not due to merely processing sound (e.g. MRI scanner noise). Inter-subject correlations in the left inferior parietal cortex were not stronger in the communication condition relative to the rest condition.

Table 6.2. Results T-test: Regions that show significantly stronger correlation values during communication than during rest.

		Global & Local maxima			Cluster-level		Voxel-level
Anatomical label	BA	X	Y	Z	K	P_{FWE}	Z
R Superior Temporal	21	60	-24	2	165	<0.001	4.88
	22	62	-10	0			4.37
	22	54	-18	0			4.03
L Superior Temporal	22	-60	-12	4	80	<0.02	4.64

6.3.1.3. Synchronous inter-subject correlations in superior temporal cortex and listener-delayed inter-subject correlations in the left anterior temporal lobe reflect processing at the form and meaning level respectively

In the above analyses (3.1.1 and 3.1.2), we focused on inter-subject correlation maps of synchronous BOLD fluctuations between speaker and listener (i.e. no time lag between the speaker's and the listener's BOLD fluctuations). Next, we explored the possibility that the listener's BOLD fluctuations may be delayed with respect to the speaker's: indeed, encoding processes may precede decoding process (Stephens et al., 2010). To test this, we analysed not only the inter-subject correlation maps based on synchronous BOLD fluctuations, but also the correlation maps between the speaker's BOLD fluctuations and the listener's with 1 TR and with 2 TR delay. We tested for an effect of the within-pairs factor Synchrony (0, 1 or 2TR delay in BOLD fluctuations for the listener relative to the speaker).

We found a main effect of Synchrony in bilateral superior temporal cortex and left anterior temporal pole (Table 6.3; Figure 6.3). Post-hoc t-tests showed that speaker-listener synchronisation in the temporal cortex is specific to the particulars of the speech signal: the effect is strongest for inter-subject correlation maps that are based on synchronous speaker-listener time series, and decreases with the increase of delay for the listener (Figure 6.3A & 6.3B). This is a strong indication that inter-subject correlations in the superior temporal cortex are driven by similarity in the (perceived) speech signal at the same specific point in time, and thus likely reflect a process related to word form rather than meaning.

We also found stronger neural coupling between speaker and listener at 1TR delay for the listener compared to maps based on synchronous activation in the left anterior temporal lobe (Figure 6.3C). The anterior temporal lobe is associated with semantic processing. Meaning encoding on the speaker's part occurs before meaning decoding on the listener's part. We might therefore find stronger inter-subject correlations in the anterior temporal lobe only when we take into account a delay for the listener.

Table 6.3. Results F-test. Main effect of *Synchrony*. Inter-subject correlations in the left anterior temporal lobe are strongest when there is 1TR delay for the listener; correlations in left and right superior temporal cortex are strongest for synchronous correlations.

		Global & Local maxima			Cluster-level		Voxel-level
Anatomical label	BA	X	Y	Z	K	P_{FWE}	*Z*
L Anterior Temporal	36	-30	8	-36	87	0.0011	5.15 *
L Superior Temporal	22	-62	-14	4	104	<0.001	4.98 .
L Superior Temporal	48	-52	-16	4			4.03
R Superior Temporal	41	46	-34	14	47	<0.05	4.5

*Cluster-level statistics obtained using SPM12. * Peak <0.05 at FWE corrected; . Peak <0.1 at FWE corrected*

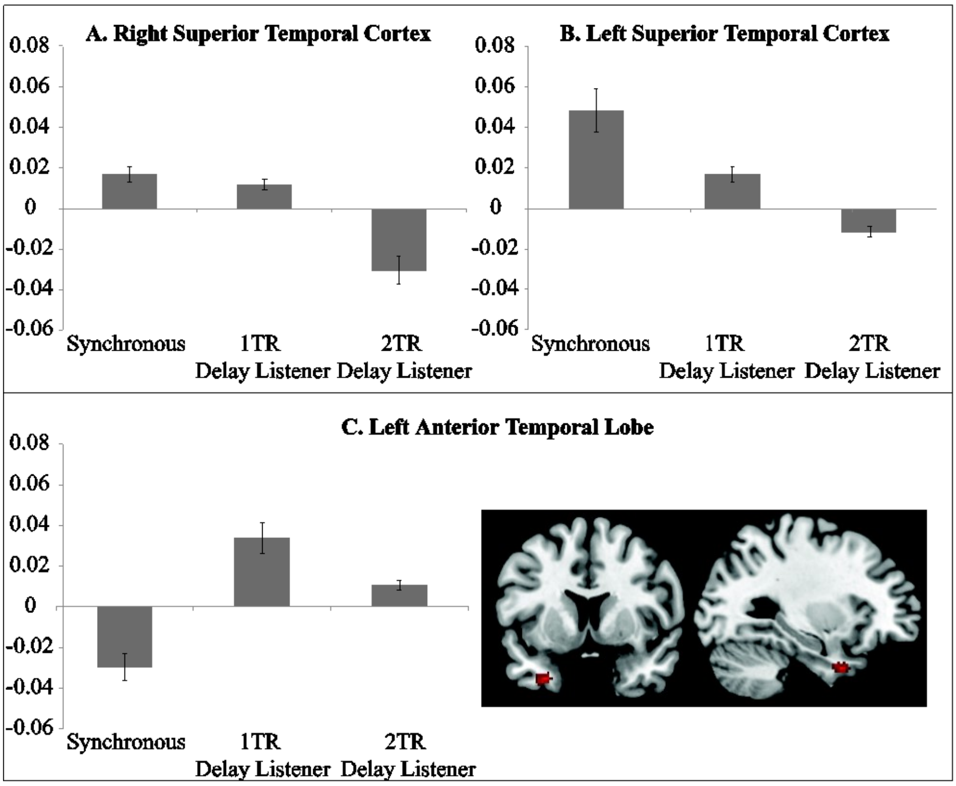

Figure 6.3. Inter-subject correlations in left and right superior temporal cortex are strongest for synchronous correlations and decrease with increased delay in activation for the listener (A & B); correlations in the left anterior temporal lobe (MNI -30 8 -36, visualized on the right) are strongest when there is 1TR delay for the listener (C).

6.3.1.4. ROI analyses in core language processing areas

We know that language processing necessarily entails syntactic and semantic processing. However, on the whole brain level, we found no inter-subject correlations in areas commonly associated with core language processes. We performed ROI analyses to explore this with more sensitivity. Based on a previous paper (Menenti, Gierhan, Segaert & Hagoort, 2011), we identified five ROIs associated with semantic/syntactic processing in language production and/or comprehension (10 mm sphere). For semantic processing, Menenti et al. found areas in the left middle temporal cortex (MNI coordinates -48, -66, 6), right middle temporal cortex (42, -66, 18) and the right precuneus (2, -60, 34). For syntactic processing, Menenti et al. found regions in the left inferior frontal gyrus (pars opercularis, -50, 10, 22) and left middle temporal (-56, -44, 4). We ran a repeated measures ANOVA with within-subject factors Region and Task Type

(Communication/Rest). There was no main effect of Task Type or Region and no interaction Task Type * Region (all $p > 0.5$).

6.3.2. Inter-subject correlation strength as a measure of speaker-listener alignment?

Next we aimed to identify an interpersonal neural signature of successful speaker-listener alignment. Speaker-listener alignment can be successful to varying degree. If inter-subject correlations reflect alignment of situation models, then we would expect the inter-subject correlation strength to positively relate to the degree to which speaker-listener alignment was successful.

In our design, the situation model that is communicated between speakers and listeners is a pair-specific zoo map. The speaker memorizes this map before describing it; after hearing this description, the listener is instructed to recreate the map. Therefore, the listener's performance on this behavioural task can be seen as a reflection of the degree of speaker-listener alignment of the representation of location-animal-enclosure combinations (i.e. the situation model).

The behavioural performance scores show that speaker-listener pairs vary greatly in the degree to which the situation model was successfully communicated. We entered the performance score in a whole-brain statistical model to identify brain regions in which the strength of inter-subject correlations was predicted by how successful speaker-listener alignment was. If inter-subject correlations reflect alignment of situation models, we expect significant effects in brain regions involved in higher-order cognition. More specifically, since the nature of the communicated situation model is spatial (speakers have to convey the location of the animal/enclosure combinations), we may find effects in regions associated with spatial memory and/or spatial mental imagery.

On the whole brain level, results showed that situation model alignment is reflected in stronger speaker-listener neural coupling in the left ventral precuneus / anterior calcarine ($p = 0.052$; Figure 6.4; Table 6.4). A control analysis showed that during rest there was no effect of communicative success on inter-subject correlation strength: during rest, there were no brain areas for which speaker-listener neural coupling was stronger the better the listener performed on the behavioural task (all $p > 0.5$). This suggests that stronger coupling in the left precuneus was related to more successful communication of the situation model, and not due to speaker-listener pairs being more similar in general, therefore finding it easier to align.

Table 6.4. Listener's performance on recreating the zoo map is positively related to inter-subject correlation strength in the left ventral precuneus / anterior calcarine.

		Global & Local maxima			Cluster-level		Voxel-level
Anatomical label	BA	X	Y	Z	K	P_{FWE}	Z
L. Precuneus	19	-26	-54	6	51	0.052	3.90
L. Precuneus	27	-20	-44	4			3.60

Figure 6.4. Listener's performance on recreating the zoo map is positively related to inter-subject correlation strength in the left ventral precuneus/anterior calcarine).

6.4. Discussion

In the current study, we explored the possibility that successful communication or speaker-listener alignment at the level of the situation model, is reflected in fMRI inter-subject correlations: correlations between temporal fluctuations in a speaker's and a listener's respective neural activation patterns, as measured by the fMRI

BOLD response. To this end, we let one set of participants (the speakers) memorize and describe abstract zoo maps, and presented these recordings to a different set of participants: the listeners. After hearing a description, the listeners were instructed to recreate the map, providing us with a measure of speaker-listener alignment or communicative success.

We reported the results from two analysis approaches. First, we investigated whether there were brain regions for which - averaged across all pairs - pairs who are coupled through a communicative (speech) signal showed significant inter-subject correlations in their BOLD responses. Hence, we looked at group averages. Our results showed significant inter-subject correlations in bilateral superior temporal cortex and left inferior parietal lobe.

The left inferior parietal lobe has been associated with various higher-order cognitive functions, ranging from social cognition (theory of mind) to semantic aspects of linguistic processing (Bzdok et al., 2016). Although due to a lack of appropriate control conditions, our design does not allow for strong claims about the function of the inferior parietal lobe in this study, it is interesting that this brain region (especially BA 7) has also been associated with visuo-spatial processes during navigation tasks (Spreng, Mar, & Kim, 2008) and visual sustained attention (Lee et al., 2013). Since the communication task in the current study requires speakers to describe a spatial map of a zoo so that listeners can recreate that map, it is likely that both describing as well as interpreting the description requires some form of visuo-spatial processing or attention.

The bilateral superior temporal cortex has been implicated in low-level processing of complex auditory stimuli such as speech. The left superior temporal cortex has been previously implicated in the production and perception of language (Okada & Hickok, 2006), more specifically concerning the phonological aspects of speech production and perception (Price, 2010). We believe that synchronous speaker-listener correlations in these regions are due to the fact that the speaker and the listener at one point in time process the same acoustic input and phonological information. This interpretation is strengthened by the within-pair comparison of the communication condition with the same pairs in rest condition (same scan duration, but no language production or comprehension). Results from this analysis indicate that the correlations in auditory cortex are not due to processing similar scanner noise: rather, they seem to be driven by producing and/or hearing the same speech signal. Further evidence in favour of this interpretation comes from an additional analysis, in which we introduce the possibility that with respect to the speaker's activation pattern, activation may be delayed for the listener. Indeed, language production processes generally precede language comprehension. However, inter-subject correlations in the superior temporal regions are strongest for synchronous correlation maps, suggesting again that these correlations are driven by similarities in the speech signal that is processed by speaker and listener.

Interestingly, speaker-listener correlations in the left anterior temporal lobe were strongest when correlation maps were based on the BOLD response of 1TR delay for the listener with respect to the speaker's BOLD response. The anterior temporal lobe is associated with the retrieval of semantic information (Visser, Jefferies, & Lambon, 2009). We believe that the reason why correlations are stronger for 1TR delay maps is that the listener will only access semantic information after hearing the verbal input, whereas the speaker needs to access semantic information before they can produce the words. That is not to say that we believe that the time difference between retrieval of semantic information for speaker and listener is exactly 1.83 seconds (1TR). Due to the sluggish nature of the BOLD response, we should not focus on the exactness of temporal information. The reported analysis was merely designed to take into account the possibility that activation for the listener is delayed with respect to the speaker.

In our second analysis approach we focused on pair-specific variation based on the listener's performance when recreating the zoo map. With this analysis, we aimed to assess whether fMRI inter-subject correlations can reflect speaker-listener alignment at the level of the situation model, or communicative success. The situation model that was communicated in the current study was well characterized in content. Therefore, we were able to form a specific hypothesis that since the situation model is highly spatial (animal-enclosure combinations tied to specific locations on a map), we should find effects of alignment success in areas responsible for spatial encoding.

On the whole brain level, there was one region in which speaker-listener correlations were stronger the better the listener in that pair performed on the behavioral task. This region was the left ventral precuneus/anterior calcarine (p = 0.052). Although we need to be careful not to over-interpret this marginally significant result, previous studies have implicated this region as part of a medial parietal network involved in spatial memory tasks and place recognition/route learning in particular (Aguirre, Detre, Alsop, & D'Esposito, 1996; Epstein, Parker, & Feiler, 2007; Schinazi & Epstein, 2010). Indeed, in a study investigating real-world route learning, Schinazi and Esptein (2010) proposed that this region plays an important role in the encoding of information regarding the spatial relationship between different locations. This process is likely to be of importance in the zoo-map task in the current study, where successful performance of the listener depends on successful transfer of information regarding the spatial relationship between animal/enclosure combinations. Future studies should replicate and further investigate the role of between-subject correlations in this area with respect to achieving communicative success when describing spatial situation models.

One important caveat of our study is that our measure of communicative success is confounded with how well the listener has memorized the speaker's description. Indeed, we cannot exclude the possibility that all listeners were able to align their situation models with the speaker's, but that some listeners were better at memorizing the described map than others. It is therefore possible that inter-subject correlations do not only reflect true speaker-listener alignment of their respective representations of the zoo-map, but that stronger inter-subject correlations in this case are driven by better memory encoding of the listener. It seems fair though to assume that a listener cannot perform well on the task without having aligned their representation of the zoo map the speaker's representation, so we believe that the inter-subject correlations at least in part reflect alignment of the zoo-map situation model. To truly dissociate between these accounts of memory and representational alignment, we should eliminate the memory component of the behavioral performance measure.

A second caveat in this study is that we have implicitly assumed that speaker-listener alignment is a static end-state of communication. However, in conversation, speakers take turns and work together to achieve alignment of situation models (Pickering & Garrod, 2004). Therefore, situation model alignment and corresponding inter-subject correlations in neural activity may be more dynamic and may change over the course of an interaction (Friston & Frith, 2015a; 2015b). Indeed, it has been previously suggested that inter-subject correlations reflect mutual adjustments to communicators' situation models (Stolk et al., 2014), not static end-states. The dynamic nature of situation models and situation model alignment would therefore better be captured in an experimental set-up that allows for bidirectional communication between interlocutors; i.e. a conversation. This would necessarily require a true hyperscanning set-up in which brain activity is measured for both interlocutors at the same time (in contrast to the current study, in which we measured speaker and listener sequentially). So far, this has been proven to be feasible with fMRI (Spiegelhalder et al., 2014; Stolk et al., 2014). Although the study by Stolk et al. (2014) was not aimed at investigating verbal communication, their paradigm was designed to test mutual understanding and allowed for bidirectional communication between participants. Therefore, this study might be a good starting point for future studies investigating the neural correlates of speaker-listener alignment.

In sum, we have shown that verbal communication leads to inter-subject correlations between the spatial and temporal activation patterns of the listener and the speaker in a communication pair. Our study is the first to show that the degree to which communication was successful (i.e. the degree to which speaker and listener have aligned their representations of the situation under discussion) can be related to the strength of inter-subject correlations in brain regions associated with processing crucial aspects of the content of the situation model that is being described. Future research into the neural mechanisms underlying successful communication should further explore these inter-subject neural markers of speaker-listener alignment.

CHAPTER 7

General Discussion

The main aim of the work conducted in this dissertation was to study language processing in the context that it is actually used: in conversation. Generally, the studies described in chapters 2 - 6 can be divided into two approaches. In chapters 2, 3 and 4, I investigated the influence of different factors that play an important role in conversation (i.e. the speaker's social and communicative goals) on a core feature of language: syntactic processing. In chapters 5 and 6, I focused on the (desired) outcome of language processing in a conversation context: communicative success. For clarity, I will discuss the main results and outstanding questions of these two lines of research separately below (sections 7.1 and 7.2), before discussing some general issues and suggestions for future research in section 7.3.

7.1. Chapters 2 - 4: Syntactic priming effects in a conversation context

In the first three empirical chapters of this dissertation, I investigated whether syntactic priming effects are influenced by top-down factors that play a role in conversation, but not in typical syntactic priming experiments. Before discussing the main results regarding this research question, I would like to note that in all studies, reliable syntactic priming effects were reported: priming of one structural alternative leads to less neural activation in brain regions associated with syntactic processing (chapter 2A), to faster speech onsets when that structure is produced again (chapters 2A and 2B) and to a tendency to choose the same alternative in a subsequent sentence (chapters 3 and 4). These findings indicate that the paradigms employed are suitable to study the effects of social factors on the magnitude of syntactic priming effects. Below, I will first summarize the main results of chapters 2, 3 and 4, focusing on whether social factors influenced the magnitude of syntactic priming effects. Then, I will discuss some outstanding questions and issues in sections 7.1.1 – 7.1.3.

The results of chapters 2A and 2B suggest that the magnitude of syntactic priming effects (measured in brain and behaviour) in a forced choice syntactic priming paradigm is not influenced by whether or not speakers are using language with the goal of communicating with their conversation partner. However, in chapter 3, a similar manipulation did lead to significant results in a free choice paradigm. Speakers who were describing photographs with the goal of communicating with their partner showed stronger syntactic priming effects (as measured in their structural choices) than speakers who were describing photographs without having anyone to talk to. Below, I discuss two possible explanations for this difference in results between chapters 2 and 3: it might be due to the difference between forced and free choice syntactic priming paradigms (section 7.1.1) and/or to the fact that syntactic choices may be influenced by more than only syntactic priming (section 7.1.2).

In chapter 2A, I reported that the syntactic priming magnitude (as measured in speech onset latencies) of one speaker is influenced by the priming magnitude of their conversation partner. In the study described in chapter 2B, however, this result was not replicated (i.e. there was a null-effect). Similar to the results in chapter 2B, the results of chapter 3 did not provide evidence that participants' syntactic priming magnitude was influenced by how strongly their conversation partner was primed by them. Together, these results indicate that the result in chapter 2A may have been a false positive: speakers do not seem to be influenced by their partner's syntactic priming magnitude. Furthermore, these studies stress the importance of replicating effects (see section 7.1.3).

Finally, the experiment in chapter 4 tested whether syntactic priming magnitude is influenced by the speaker's goal of making a positive impression on their partner. However, results showed that speakers' syntactic priming magnitude was not influenced by this goal. We additionally tested whether syntactic alignment influences how likeable speakers appear to their partner. In the first study reported in chapter 4, we found a negative effect of how much one speaker aligned with their partner's syntactic choices on how that partner evaluated them on a post-experiment questionnaire. However, we did not replicate this effect in study 2 (there was no significant positive or negative relationship), indicating - at the very least - that the effect of a speaker's syntactic priming magnitude on perceived likeability is not a robust effect (and again stressing the importance of replicating results, see section 7.1.3).

7.1.1. Forced vs. free choice syntactic priming paradigms: diverging results

In this dissertation, two paradigms were used to study the effect of syntactic priming on sentence processing: a free choice and a forced choice paradigm. In the free choice paradigm, participants were presented with black and white photographs that could be described correctly in two different ways: with a sentence in the active (the man is kissing the woman) or in the passive voice (the boy is being hugged by the girl). Participants were free to choose either passive or active voice to describe the photograph. In the forced choice paradigm, participants were not free to choose the syntax themselves. By color-coding the pictures (one actor in green, one actor in red) and instructing the participants to always describe the green figure before the red figure, they were forced to produce a sentence in the active voice (the agent is green, e.g. the man in a scene where a man kisses a woman) or a sentence in the passive voice (the patient is green, e.g. the woman in a scene where a man kisses a woman).

The reason why two different paradigms were used was that it was not possible to use the same paradigm for all the studies reported in chapters 2-4. Indeed, due to the low frequency of passive sentence production in free choice paradigms, there would not be enough trials to make a reliable statistical comparison between primed and non-primed trials in the noisy BOLD signal that is measured in fMRI studies. When looking at syntactic priming effects in the brain, forced-choice paradigms are therefore a better (perhaps the only) option, since it provides the experimenter with control over the number of trials that participants describe with a passive sentence.

I would like to stress that, overall, the results reported in the first 3 empirical chapters of this dissertation show that both free choice and forced choice syntactic priming paradigms can be used to show that there is a facilitating effect of processing repeated sentence structure, as reflected in syntactic priming effects. As said above, in chapter 2A, we showed significant repetition suppression effects in syntax-related brain areas when participants processed sentences with repeated relative to novel syntactic structure. A similar effect was found for speech onset latencies in this chapter, as well as in replication chapter 2B: speakers' speech onset latencies were shorter for sentences with repeated structure relative to novel structure. In chapters 3 and 4 we report significant priming effects on speaker's syntactic choices: speakers produce more sentences in the passive voice after hearing a passive prime sentence than after hearing a baseline (intransitive) prime sentence. Thus, when studying how processing syntactic structure in one sentence influences production and/or comprehension of the next sentence, both paradigms are useful and yield reliable syntactic priming effects..

However, the two paradigm types may not be equally suited for studying top-down effects of being in a conversation on the magnitude of syntactic priming effects. This may be the reason why we find an effect of communicative context on the magnitude of speaker's syntactic priming effects in the free choice paradigm (chapter 3), but not in the forced choice paradigm (chapter 2). Indeed, there is a crucial difference between the communicative conditions in the two paradigms. In the free choice paradigm, the participants' main task is to describe the photographs to their conversation partner. Although they are restricted in how to describe the photographs (i.e. 'the man is kissing the woman' and not 'he is kissing her'), after sufficient practice, they know what kind of sentences are expected of them and this is no longer a demanding task. Their main task is thus to describe the photographs so that their partner can decide whether they are presented with the same photograph or not. In the communicative context of the forced choice paradigm, participants are also instructed to describe the photographs so that their conversation partner can make this decision. However, participants in the forced choice paradigm have the additional, demanding task of always naming the green figure they see on the photograph before the red figure. It is possible that their goal to perform well on the latter task (describe the green figure before the red figure) is more dominant than their communicative goal. Certainly, participants have no choice in how to describe the photographs and cannot actually do anything to facilitate communication for the listener other than describing the photographs correctly. If the participants' goal to perform well on the description task is more dominant than their communicative goal, this might explain why the syntactic priming magnitude is similar in the communicative and non-communicative contexts in a forced choice syntactic priming paradigm, even though communicative context can affect syntactic priming magnitude (as is evident from the results reported in chapter 3).

7.1.2. An alternative explanation: syntactic choice = priming effect + social goals

An alternative (but not necessarily mutually exclusive) explanation for why having a communicative goal leads to stronger priming effects in speaker's syntactic choices (chapter 3) but not to stronger syntactic priming effects in BOLD response or speech onset latencies (chapter 2) is that syntactic choice is more than just the result of syntactic priming alone, and the influence of social goals is not on syntactic priming effect directly, but can be an additional factor that influences syntactic choice. To examine this alternative explanation, I will now discuss two accounts explaining how social factors could interact with syntactic priming when we look at syntactic choice data.

One possibility is that the speaker's social goals directly influence language comprehension in the prime phase, and therefore affect how strongly this prime influences subsequent production of the target (Branigan et al., 2007; Weatherholtz et al., 2014 - see Figure 7.1A). These accounts have been used to explain results of previous studies, in which authors report an effect of social context on the magnitude of syntactic priming effects (syntactic alignment). Weatherholtz et al. (2014), for example, report that syntactic alignment is influenced by how similar speakers perceive themselves to be to their partner (this construct is similar to what I have termed 'likeability of the speaker' in the studies described above). They argue that such contextual factors influence how listeners encode the syntactic structure of a prime sentence, due to different allocation of attentional resources. More attention to the prime structure would lead to stronger syntactic priming effects. A similar account has been proposed by Branigan et al. (2007), who report that participants align their syntactic structures more when they had been addressed by the speaker while listening to the prime sentence than when they were merely overhearers during the prime phase. Branigan et al. propose that listeners allocate more attentional resources to processing the prime sentence when they are addressees, and thus might have to respond to what the speaker is telling them, than when they are overhearers. This would, in turn, explain why syntactic priming effects are stronger for addressees than for overhearers.

On their own, the results of chapter 3 could be explained by such an account: having a communicative goal could lead to more attentive processing of the prime sentence, which may then lead to a stronger priming magnitude in the communicative relative to the non-communicative context. However, if this were the case, one would also expect to see an effect of communicative context on syntactic priming magnitude in chapter 2. Indeed, if the difference between communicative and non-communicative context affects syntactic encoding in the prime phase, we should find no differences between the two studies: in both chapter 2 and 3, the difference in communicative context during the prime phase was that in the non-communicative context, participants listened to recorded sentences and in the communicative context, they listened to the descriptions from their conversation partner. If having a communicative goal affects how primes are encoded, we should therefore have seen an effect of communicative context on syntactic priming magnitude in both studies.

An alternative account for why social context influences syntactic priming effects in choices is that syntactic choice is more than just the result of syntactic priming (Figure 7.1B). Indeed, even when primed, in a natural situation, there may be many factors that affect whether structure is actually repeated. Examples of factors that influence syntactic choice are thematic structure (agents are likely to be placed in the subject position; Ferreira, 1994), information focus (if conceptual focus is placed on the actor, participants are more likely to produce an active; Tannenbaum & Williams, 1968), and so on. Pragmatic factors, such as the speaker's goal to facilitate comprehension for their partner, may also influence syntactic choice. Such an account would explain why there was an influence of speakers using language with the goal of communicating on the magnitude of syntactic priming effects in speakers' syntactic choices, but not on speech onset latencies or brain activation, which may be a purer reflection of the facilitating effect of syntactic priming alone.

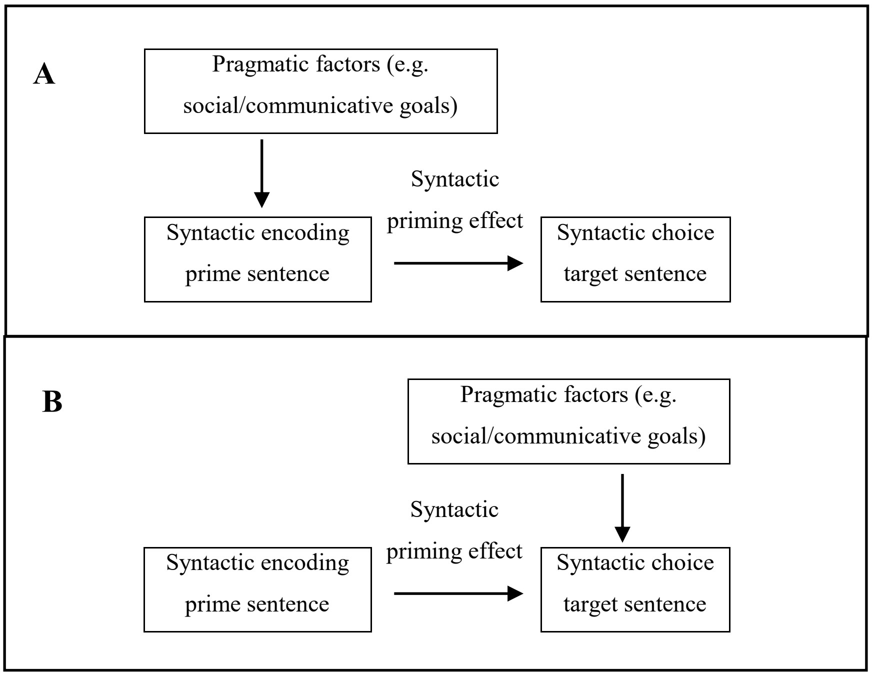

Figure 7.1 Two possibilities of how speaker's social goals could interact with syntactic priming effects to affect syntactic choice. A) Social goals influence syntactic encoding of the prime sentence therefore influence the magnitude of syntactic priming effects. B) Syntactic priming effects could be independent of social goals and together influence syntactic choice.

7.1.3. Speakers are not reliably influenced by their partner's priming magnitude

Across the four studies described in chapters 2 - 4, I not only investigated the effect of speaker's social goals on how strongly they were primed by their conversation partner, I also investigated how their conversation partner's priming magnitude influenced them. Indeed, in a real life situation, speakers are not only primed by their partner's syntactic choices; their partner is also primed by their syntactic choices. I explored the effect of a conversation partner's syntactic priming magnitude on a participant's own syntactic priming magnitude (chapters 2 and 3) and the effect of their conversation partner's priming magnitude on how likeable they appear to the participant (chapter 4).

In chapter 2A, the results indicated that the syntactic priming magnitude of one speaker is influenced by the priming magnitude of their partner; we found that if one speaker is strongly primed by the other speaker in a conversation pair, the other speaker is also strongly primed by the first speaker. Although this result may fit with other findings that have shown that speakers imitate each other on low-level behavioural features (e.g. accent (Giles & Powesland, 1975), speech rate (Webb, 1969) and speech rhythm (Cappella & Planalp, 1981)), we do not want to make strong claims about this result because, in chapter 2B, it did not replicate. Furthermore, we also manipulated the partner's syntactic priming magnitude (i.e. how likely the partner was to repeat the participant's syntactic choices) in chapter 3. However, we again found no evidence to support the hypothesis that one speaker's syntactic priming magnitude is influenced by their partners' priming magnitude. It is therefore likely that the result reported in chapter 2A was a false positive.

The aim of chapter 4 was to test the hypothesis that syntactic alignment can be used by speakers to mediate social relationships: I tested whether speakers align their syntactic choices more when they want to be liked by their partner. Crucially, the experiment was designed so that we could also measure the effect of one speaker's syntactic priming magnitude on how the other speaker evaluated them. In other words, the design allowed us to test whether syntactic alignment is an effective way to achieve social goals. In the first experiment reported in chapter 4, we found a negative effect of the primed participant's syntactic priming magnitude on how their partner evaluated them; the more a participant aligned with their partner's syntactic choices, the more that partner decreased their evaluation of that participant with respect to their likeability. However, this effect was not replicated in a second experiment. Crucially, there was no a priori reason to expect a difference in the two studies. We therefore have to conclude that the syntactic alignment of one speaker in a communicative pair is not a reliable predictor of how likeable that participant appears to their conversation partner.

Although it is disappointing to see your results fail to replicate, the findings reported in this dissertation once more stress the importance of replicating experimental findings (see also: Open Science Collaboration, 2015). While one should be cautious when interpreting null results, null findings can be informative to the field in many ways and should therefore also be reported.

7.2. Chapters 5-6: A two-brain approach to communication in conversation

A relatively recent development in the field of social cognitive neuroscience is investigating social interactions with a multiple-brain approach. This means measuring the brain activity of two (or more) participants in a social interaction and investigating the inter-personal relationship between their spatial and temporal brain activity patterns. Since conversation is one of the most common social interactions we have in our daily lives, it seems intuitive to apply the two-brain approach to conversation.

Before using this method, though, I took a step back and considered what such a two-brain approach to conversation can tell us which the traditional one-brain approach cannot. Indeed, although intuitively it seems to make sense to use a two-brain approach to a two-brain process such as conversation, a theoretical framework that leads to clear hypotheses about the neural mechanisms leading to between-brain interactions was lacking. In chapter 5, I argued that the unique contribution of the two-brain approach would be to study the neural mechanisms that underlie communicative success. Based on a recently proposed theoretical framework (Friston & Frith 2015a; 2015b) I argued that between-brain correlations reflect between-subject alignment at different levels of linguistic and extra-linguistic processing. The ultimate extension of this hypothesis would be that between-brain correlations could reflect between-subject alignment at the highest level possible: alignment of situation models or, in other words, communicative success (Pickering & Garrod, 2004).

In chapter 6, then, I tested whether between-subject correlations can reflect alignment at this ultimate level: situation model alignment. Using fMRI, brain activity (reflected in the BOLD response) was measured for a speaker and a listener in a communicative pair. The results do not only indicate that participating in a communicative exchange leads to involvement of similar brain areas in speaker and listener, but also that speaker-listener alignment at the level of the situation model is reflected in the strength of between-brain neural coupling in a region associated with processing of crucial aspects of the situation model.

7.2.1. Communication is not conversation

Although the aim in this thesis was to study language processing in a conversation context, participants in the two-brain study in chapter 6 were definitely not engaged in a conversation. Indeed, speakers were producing a monologue and listeners listened to a recording of that monologue at a later point in time. This is very different from conversation or dialogue, where interlocutors take turns and work together to align their representations of the situation under discussion.

However, together with the framework presented in chapter 5, the empirical study described in chapter 6 is a stepping stone towards a two-brain approach to conversation. Indeed, communication plays an important role in monologue as well as dialogue (conversation). However, future studies that aim to take a two-brain approach to language processing in conversation should move away from defining communicative success (mutual understanding or alignment of situation models) as a static end-state of communication. In chapter 5, I argued that mutual understanding is better conceptualized as a dynamical process reflecting continuous updates in the situation model in the brains of both interlocutors.

7.3. Future directions

In this dissertation, I have used multiple experimental paradigms to study language processing in a conversation context. The experimental paradigms that were employed in chapters 2 - 4 were designed to study the top-down effects of being in a conversation context (targeting the influence of specific aspects of this context in different studies) on a well-known phenomenon in the psycholinguistic literature: syntactic priming effects. In chapter 2A, participants lay in the MRI scanner and interacted with another participant in a different room via a real-time connection. In the experiment described in chapter 3, participants interacted with a confederate. I additionally manipulated the adaptiveness of the confederate, to create a more natural situation in which the participant cannot only be primed by their partner, but the partner is also primed by the participant. In chapter 4, I developed a paradigm in which we can measure syntactic priming effects for one speaker, while they are interacting with another, naive participant, crucially without losing experimental control.

While not all experimental manipulations found significant differences, by replicating well-established effects in a more natural, conversation-like context, I have increased the ecological validity of these results. Equally importantly, I have shown that it is possible to investigate language processing in a more natural context without losing experimental control. The latter is also true for the paradigm employed in chapter 6. I showed that it is possible to measure the brain activity of two participants involved in a controlled communication task and extract useful information from the relationship between the brain activities of the two individuals (between-brain neural coupling).

Together, the work in this thesis opens up possibilities for investigating language processing while taking into account contextual and communicative constraints and influences. This is an important future direction for research aiming to extend the study of language processing to include the study of the (neuro-) cognitive mechanisms that underlie successful communication in a conversational context.

7.4. Conclusion

The study of language processing in natural contexts, such as a conversation, contributes to a fuller picture of how the brain enables people to function in daily life. Although traditional experiments in which participants are asked to produce or comprehend language in an isolated environment can be informative in many ways, more studies should take into account the possible influence of (conversational) context. When studying the cognitive mechanisms that underlie language processing, it is important not to restrict ourselves to questions such as: how does the brain enable us to produce or comprehend language? An equally important question is: how does the brain enable us to communicate effectively in a social context?

References

Aguirre, G. K., Detre, J. A., Alsop, D. C., & D'Esposito, M. (1996). The parahippocampus subserves topographical learning in man. *Cerebral Cortex (New York, N.Y.: 1991)*, *6*(6), 823–829.

Anders, S., Heinzle, J., Weiskopf, N., Ethofer, T., & Haynes, J.-D. (2011). Flow of affective information between communicating brains. *Neuroimage*, *54*(1–4), 439–446. https://doi.org/10.1016/j.neuroimage.2010.07.004

Arai, M., van Gompel, R. P. G., & Scheepers, C. (2007). Priming ditransitive structures in comprehension. *Cognitive Psychology*, *54*(3), 218–250. https://doi.org/10.1016/j.cogpsych.2006.07.001

Awad, M., Warren, J. E., Scott, S. K., Turkheimer, F. E., & S, J. (2007). A common system for the comprehension and production of narrative speech. *The Journal of Neuroscience*, *27*(43), 11455–11464. https://doi.org/10.1523/JNEUROSCI.5257-06.2007

Babiloni, F., & Astolfi, L. (2014). Social neuroscience and hyperscanning techniques: Past, present and future. *Neuroscience & Biobehavioral Reviews*, *44*, 76–93. https://doi.org/10.1016/j.neubiorev.2012.07.006

Balcetis, E., & Dale, R. (2005). An exploration of social modulation of syntactic priming. *Proceedings of the 27th Annual Meeting of the Cognitive Science Society*, 184–189.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/ j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting Linear Mixed-Effects Models using lme4. *arXiv:1406.5823 [Stat]*. Retrieved from http://arxiv.org/abs/1406.5823

Bates, D., Maechler, M., & Bolker, B. (2012). lme4: Linear mixed-effects models using S4 classes (2011). R package version 0.999375-42.

Bell, A. (1984). Language style as audience design. *Language in Society*, *13*(2), 145–204. https://doi.org/10.1017/S004740450001037X

Bernolet, S., & Hartsuiker, R. J. (2010). Does verb bias modulate syntactic priming? *Cognition*, *114*(3), 455–461. https://doi.org/10.1016/j.cognition.2009.11.005

Bernolet, S., Hartsuiker, R. J., & Pickering, M. J. (2009). Persistence of emphasis in language production: A cross-linguistic approach. *Cognition*, *112*(2), 300–317. https://doi.org/10.1016/j.cognition.2009.05.013

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, *18*(3), 355–387. https://doi.org/10.1016/0010-0285(86)90004-6

Bock, K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition*, *104*(3), 437–458. https://doi.org/10.1016/j.cognition.2006.07.003

Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General*, *129*(2), 177–192. https://doi.org/10.1037/0096-3445.129.2.177

Bock, K., & Loebell, H. (1990). Framing sentences. *Cognition*, *35*(1), 1–39. https://doi.org/10.1016/0010-0277(90)90035-I

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision*, *10*(4), 433–436.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, *75*(2), B13–B25. https://doi.org/10.1016/S0010-0277(99)00081-5

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming Prepositional-Phrase Attachment During Comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(3), 468–481. https://doi.org/10.1037/0278-7393.31.3.468

Branigan, H. P., Pickering, M. J., McLean, J. F., & Cleland, A. A. (2007). Syntactic alignment and participant role in dialogue. *Cognition*, *104*(2), 163–197. https://doi.org/10.1016/j.cognition.2006.05.006

Branigan, H. P., Pickering, M. J., Pearson, J., & McLean, J. F. (2010). Linguistic alignment between people and computers. *Journal of Pragmatics*, *42*(9), 2355–2368. https://doi.org/10.1016/j.pragma.2009.12.012

Branigan, H. P., Pickering, M. J., Pearson, J., McLean, J. F., & Brown, A. (2011). The role of beliefs in lexical alignment: Evidence from dialogs with humans and computers. *Cognition*, *121*(1), 41–57. https://doi.org/10.1016/j.cognition.2011.05.011

Branigan, H. P., Pickering, M. J., Pearson, J., McLean, J. F., & Nass, C. I. (2003). Syntactic alignment between computers and people: the role of belief about mental states. Lawrence Erlbaum Associates. Retrieved from https://repository.abertay.ac.uk/jspui/handle/10373/2078

Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(6), 1482–1493. https://doi.org/10.1037/0278-7393.22.6.1482

Buur, P. F., Poser, B. A., & Norris, D. G. (2009). A dual echo approach to removing motion artefacts in fMRI time series. *NMR in Biomedicine*, *22*(5), 551–560. https://doi.org/10.1002/nbm.1371

Bzdok, D., Hartwigsen, G., Reid, A., Laird, A. R., Fox, P. T., & Eickhoff, S. B. (2016). Left inferior parietal lobe engagement in social cognition and language. *Neuroscience & Biobehavioral Reviews*, *68*, 319–334. https://doi.org/10.1016/j.neubiorev.2016.02.024

Cappella, J. N., & Planalp, S. (1981). Talk and Silence Sequences in Informal Conversations Iii: Interspeaker Influence. *Human Communication Research*, *7*(2), 117–132. https://doi.org/10.1111/j.1468- 2958.1981.tb00564.x

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, *3*(4), 572–582. https://doi.org/10.1016/0093-934X(76)90048-1

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review*, *113*(2), 234–272. https://doi.org/10.1037/0033-295X.113.2.234

Chang, F., Dell, G. S., Bock, K., & Griffin, Z. M. (2000). Structural Priming as Implicit Learning: A Comparison of Models of Sentence Production. *Journal of Psycholinguistic Research*, *29*(2), 217–230. https://doi.org/10.1023/A:1005101313330

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology*, *76*(6), 893–910. https://doi.org/10.1037/0022-3514.76.6.893

Clark, H. H., & Chase, W. G. (1972). On the process of comparing sentences against pictures. *Cognitive Psychology*, *3*(3), 472–517. https://doi.org/10.1016/0010-0285(72)90019-9

Collaboration, O. S. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716. https://doi.org/10.1126/science.aac4716

Corley, M., & Scheepers, C. (2002). Syntactic priming in English sentence production: Categorical and latency evidence from an Internet-based study. *Psychonomic Bulletin & Review*, *9*(1), 126–131. https://doi.org/10.3758/BF03196267

Coyle, J. M., & Kaschak, M. P. (2012). Female Fertility Affects Men's Linguistic Choices. *PLoS ONE*, *7*(2), e27971. https://doi.org/10.1371/journal.pone.0027971

Dikker, S., Silbert, L. J., Hasson, U., & Zevin, J. D. (2014). On the Same Wavelength: Predictable Language Enhances Speaker–Listener Brain-to-Brain Synchrony in Posterior Superior Temporal Gyrus. *The Journal of Neuroscience*, *34*(18), 6267–6272. https://doi.org/10.1523/JNEUROSCI.3796-13.2014

Dumas, G., Lachat, F., Martinerie, J., Nadel, J., & George, N. (2011). From social behaviour to brain synchronization: Review and perspectives in hyperscanning. *IRBM*, *32*(1), 48–53. https://doi.org/10.1016/j.irbm.2011.01.002

Epstein, R. A., Parker, W. E., & Feiler, A. M. (2007). Where am I now? Distinct roles for parahippocampal and retrosplenial cortices in place recognition. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *27*(23), 6141–6149. https://doi.org/10.1523/JNEUROSCI.0799-07.2007

Ferreira, F. (1994). Choice of Passive Voice is Affected by Verb Type and Animacy. *Journal of Memory and Language*, *33*(6), 715–736. https://doi.org/10.1006/jmla.1994.1034

Ferreira, V. S. (2003). The persistence of optional complementizer production: Why saying "that" is not saying "that" at all. *Journal of Memory and Language*, *48*(2), 379–398. https://doi.org/10.1016/S0749-596X(02)00523-5

Ferreira, V. S., Kleinman, D., Kraljic, T., & Siu, Y. (2012). Do priming effects in dialogue reflect partner- or task-based expectations? *Psychonomic Bulletin & Review*, *19*(2), 309–316. https://doi.org/10.3758/s13423-011-0191-9

Friston, K. (2005). A theory of cortical responses. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1456), 815–836. https://doi.org/10.1098/rstb.2005.1622

Friston, K., Ashburner, J. T., Kiebel, S. J., Nichols, T. E., & Penny, W. D. (2007). Statistical parametric mapping. In K. J. Friston (Ed.), *Statistical parametric mapping: the analysis of functional brain images* (pp. 10–31). Amsterdam: Elsevier. Retrieved from http://eprints.ucl.ac.uk/65582/

Friston, K., & Frith, C. (2015). A Duet for one. *Consciousness and Cognition*, *36*, 390–405. https://doi.org/10.1016/j.concog.2014.12.003

Friston, K. J., & Frith, C. D. (2015). Active inference, communication and hermeneutics. *Cortex*, *68*, 129–143. https://doi.org/10.1016/j.cortex.2015.03.025

Ganel, T., Gonzalez, C. L. R., Valyear, K. F., Culham, J. C., Goodale, M. A., & Köhler, S. (2006). The relationship between fMRI adaptation and repetition priming. *NeuroImage*, *32*(3), 1432–1440. https://doi.org/10.1016/j.neuroimage.2006.05.039

Garrod, S., & Pickering, M. J. (2009). Joint Action, Interactive Alignment, and Dialog. *Topics in Cognitive Science*, *1*(2), 292–304. https://doi.org/10.1111/j.1756-8765.2009.01020.x

Giles, H., & Powesland, P. F. (1975). *Speech style and social evaluation* (Vol. viii). Oxford, England: Academic Press.

Gries, S. T. (2011). Studying syntactic priming in corpora: Implications of different levels of granularity. In *Human Cognitive Processing*.

Grill-Spector, K., & Malach, R. (2001). fMR-adaptation: a tool for studying the functional properties of human cortical neurons. *Acta Psychologica*, *107*(1–3), 293–321. https://doi.org/10.1016/S0001-6918(01)00019-1

Griswold, M. A., Jakob, P. M., Heidemann, R. M., Nittka, M., Jellus, V., Wang, J., Haase, A. (2002). Generalized autocalibrating partially parallel acquisitions (GRAPPA). *Magnetic Resonance in Medicine*, *47*(6), 1202–1210. https://doi.org/10.1002/mrm.10171

Hanulíková, A., van Alphen, P. M., van Goch, M. M., & Weber, A. (2011). When One Person's Mistake Is Another's Standard Usage: The Effect of Foreign Accent on Syntactic Processing. *Journal of Cognitive Neuroscience*, *24*(4), 878–887. https://doi.org/10.1162/jocn_a_00103

Hari, R., Henriksson, L., Malinen, S., & Parkkonen, L. (2015). Centrality of Social Interaction in Human Brain Function. *Neuron*, *88*(1), 181–193. https://doi.org/10.1016/j.neuron.2015.09.022

Hartsuiker, R. J. (1999). Priming Word Order in Sentence Production. *The Quarterly Journal of Experimental Psychology Section A*, *52*(1), 129–147. https://doi.org/10.1080/713755798

Hartsuiker, R. J., & Kolk, H. H. J. (1998). Syntactic Persistence in Dutch. *Language and Speech*, *41*(2), 143–184. https://doi.org/10.1177/002383099804100202

Haselton, M. G., & Miller, G. F. (2006). Women's fertility across the cycle increases the short-term attractiveness of creative intelligence. *Human Nature*, *17*(1), 50–73. https://doi.org/10.1007/s12110-006-1020-0

Hasson, U., Ghazanfar, A. A., Galantucci, B., Garrod, S., & Keysers, C. (2012). Brain-to-brain coupling: a mechanism for creating and sharing a social world. *Trends in Cognitive Sciences*, *16*(2), 114–121. https://doi.org/10.1016/j.tics.2011.12.007

Heyselaar, E., Hagoort, P., & Segaert, K. (2014). In dialogue with an avatar, syntax production is identical compared to dialogue with a human partner. In P. Bello, M. Guarini, M. McShane, & B. Scassellati (Eds.), *Proceedings of the*

36th Annual Meeting of the Cognitive Science Society (CogSci 2014) (pp. 2351–2356). Quebec City: Cognitive Science Society.

Heyselaar, E., Hagoort, P., & Segaert, K. (2015). In dialogue with an avatar, language behavior is identical to dialogue with a human partner. *Behavior Research Methods*, 1–15. https://doi.org/10.3758/s13428-015-0688-7

Indefrey, P., Brown, C. M., Hellwig, F., Amunts, K., Herzog, H., Seitz, R. J., & Hagoort, P. (2001). A neural correlate of syntactic encoding during speech production. *Proceedings of the National Academy of Sciences*, *98*(10), 5933–5936. https://doi.org/10.1073/pnas.101118098

Jaeger, T. F., & Snider, N. E. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition*, *127*(1), 57–83. https://doi.org/10.1016/j.cognition.2012.10.013

Jiang, J., Dai, B., Peng, D., Zhu, C., Liu, L., & Lu, C. (2012). Neural Synchronization during Face-to-Face Communication. *The Journal of Neuroscience*, *32*(45), 16064–16069. https://doi.org/10.1523/JNEUROSCI.2926-12.2012

Kaschak, M. P., Loney, R. A., & Borreggine, K. L. (2006). Recent experience affects the strength of structural priming. *Cognition*, *99*(3), B73–B82. https://doi.org/10.1016/j.cognition.2005.07.002

Konvalinka, I., & Roepstorff, A. (2012). The two-brain approach: how can mutually interacting brains teach us something about social interaction? *Frontiers in Human Neuroscience*, *6*. https://doi.org/10.3389/fnhum.2012.00215

Kuhlen, A. K., Allefeld, C., & Haynes, J.-D. (2012). Content-specific coordination of listeners' to speakers' EEG during communication. *Frontiers in Human Neuroscience*, *6*. https://doi.org/10.3389/fnhum.2012.00266

Lee, J., Ku, J., Han, K., Park, J., Lee, H., Kim, K. R., … Kim, S. I. (2013). rTMS over bilateral inferior parietal cortex induces decrement of spatial sustained attention. *Frontiers in Human Neuroscience*, *7*. https://doi.org/10.3389/fnhum.2013.00026

Lev-Ari, S. (2015). Selective Grammatical Convergence: Learning From Desirable Speakers. *Discourse Processes*, *0*(0), 1–18.

https://doi.org/10.1080/0163853X.2015.1094716

Mahowald, K., James, A., Futrell, R., & Gibson, E. (n.d.). A meta-analysis of syntactic priming in language production. *Journal of Memory and Language*. https://doi.org/10.1016/j.jml.2016.03.009

Menenti, L., Garrod, S. C., & Pickering, M. J. (2012). Toward a neural basis of interactive alignment in conversation. *Frontiers in Human Neuroscience*, *6*, 185. https://doi.org/10.3389/fnhum.2012.00185

Menenti, L., Gierhan, S. M. E., Segaert, K., & Hagoort, P. (2011). Shared Language Overlap and Segregation of the Neuronal Infrastructure for Speaking and Listening Revealed by Functional MRI. *Psychological Science*, *22*(9), 1173–1182. https://doi.org/10.1177/0956797611418347

Menenti, L., Segaert, K., & Hagoort, P. (2012). The neuronal infrastructure of speaking. *Brain and Language*, *122*(2), 71–80. https://doi.org/10.1016/j.bandl.2012.04.012

Ménoret, M., Varnet, L., Fargier, R., Cheylus, A., Curie, A., des Portes, V., … Paulignan, Y. (2014). Neural correlates of non-verbal social interactions: A dual-EEG study. *Neuropsychologia*, *55*, 85–97. https://doi.org/10.1016/j.neuropsychologia.2013.10.001

Montague, P. R., Berns, G. S., Cohen, J. D., McClure, S. M., Pagnoni, G., Dhamala, M., … Fisher, R. E. (2002). Hyperscanning: Simultaneous fMRI during Linked Social Interactions. *NeuroImage*, *16*(4), 1159–1164. https://doi.org/10.1006/nimg.2002.1150

Myslín, M., & Levy, R. (2016). Comprehension priming as rational expectation for repetition: Evidence from syntactic processing. *Cognition*, *147*, 29–56. https://doi.org/10.1016/j.cognition.2015.10.021

Nieuwland, M. S., & Van Berkum, J. J. A. (2006). When Peanuts Fall in Love: N400 Evidence for the Power of Discourse. *Journal of Cognitive Neuroscience*, *18*(7), 1098–1111. https://doi.org/10.1162/jocn.2006.18.7.1098

Noppeney, U., & Price, C. J. (2004). An fMRI Study of Syntactic Adaptation. *Journal of Cognitive Neuroscience*, *16*(4), 702–713. https://doi.org/10.1162/089892904323057399

Okada, K., & Hickok, G. (2006). Left posterior auditory-related cortices participate both in speech perception and speech production: Neural overlap revealed by fMRI. *Brain and Language*, *98*(1), 112–117. https://doi.org/10.1016/j.bandl.2006.04.006

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: transforming numbers into movies. *Spatial Vision*, *10*(4), 437–442. https://doi.org/10.1163/156856897X00366

Pickering, M. J., & Branigan, H. P. (1998). The Representation of Verbs: Evidence from Syntactic Priming in Language Production. *Journal of Memory and Language*, *39*(4), 633–651. https://doi.org/10.1006/jmla.1998.2592

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, *27*(2), 169–226. https://doi.org/10.1017/S0140525X04000056

Pickering, M. J., & Garrod, S. (2014). Neural integration of language production and comprehension. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(43), 15291–15292. https://doi.org/10.1073/pnas.1417917111

Poser, B. A., Versluis, M. J., Hoogduin, J. M., & Norris, D. G. (2006). BOLD contrast sensitivity enhancement and artifact reduction with multiecho EPI: Parallel-acquired inhomogeneity-desensitized fMRI. *Magnetic Resonance in Medicine*, *55*(6), 1227–1235. https://doi.org/10.1002/mrm.20900

Potter, M. C., & Lombardi, L. (1998). Syntactic Priming in Immediate Recall of Sentences. *Journal of Memory and Language*, *38*(3), 265–282. https://doi.org/10.1006/jmla.1997.2546

Price, C. J. (2010). The anatomy of language: a review of 100 fMRI studies published in 2009. *Annals of the New York Academy of Sciences*, *1191*(1), 62–88. https://doi.org/10.1111/j.1749-6632.2010.05444.x

R Core Development Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from /www.R-project.org/.

Reise, S. P., Ventura, J., Nuechterlein, K. H., & Kim, K. H. (2005). An Illustration of Multilevel Factor Analysis. *Journal of Personality Assessment*, *84*(2), 126–136. https://doi.org/10.1207/s15327752jpa8402_02

Reitter, D., Keller, F., & Moore, J. D. (2006). Computational modelling of structural priming in dialogue. In *Proceedings of the Human Language Technology Conference of the NAACL, Companion Volume: Short Papers* (pp. 121–124). Stroudsburg, PA, USA: Association for Computational Linguistics. Retrieved from http://dl.acm.org/citation.cfm?id=1614049.1614080

Reitter, D., Keller, F., & Moore, J. D. (2011). A Computational Cognitive Model of Syntactic Priming. *Cognitive Science*, *35*(4), 587–637. https://doi.org/10.1111/j.1551-6709.2010.01165.x

Reitter, D., Moore, J. D., & Keller, F. (2010). Priming of Syntactic Rules in Task-Oriented Dialogue and Spontaneous Conversation. Retrieved from https://www.era.lib.ed.ac.uk/handle/1842/4178

Scheepers, C. (2003). Syntactic priming of relative clause attachments: persistence of structural configuration in sentence production. *Cognition*, *89*(3), 179–205. https://doi.org/10.1016/S0010-0277(03)00119-7

Schinazi, V. R., & Epstein, R. A. (2010). Neural correlates of real-world route learning. *NeuroImage*, *53*(2), 725–735. https://doi.org/10.1016/j.neuroimage.2010.06.065

Schippers, M. B., Roebroeck, A., Renken, R., Nanetti, L., & Keysers, C. (2010). Mapping the information flow from one brain to another during gestural communication. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(20), 9388–9393. https://doi.org/10.1073/pnas.1001791107

Schoot, L., Hagoort, P., & Segaert, K. (2016). What can we learn from a two-brain approach to verbal interaction? *Neuroscience & Biobehavioral Reviews*, *68*, 454–459. https://doi.org/10.1016/j.neubiorev.2016.06.009

Schoot, L., Heyselaar, E., Hagoort, P., & Segaert, K. (2016). Does Syntactic Alignment Effectively Influence How Speakers Are Perceived by Their Conversation Partner? *PLOS ONE*, *11*(4), e0153521.

https://doi.org/10.1371/journal.pone.0153521

Schoot, L., Menenti, L., Hagoort, P., & Segaert, K. (2014). A little more conversation – the influence of communicative context on syntactic priming in brain and behavior. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00208

Segaert, K., Kempen, G., Petersson, K. M., & Hagoort, P. (2013). Syntactic priming and the lexical boost effect during sentence production and sentence comprehension: An fMRI study. *Brain and Language*, *124*(2), 174–183. https://doi.org/10.1016/j.bandl.2012.12.003

Segaert, K., Menenti, L., Weber, K., & Hagoort, P. (2011). A Paradox of Syntactic Priming: Why Response Tendencies Show Priming for Passives, and Response Latencies Show Priming for Actives. *PLoS ONE*, *6*(10), e24209. https://doi.org/10.1371/journal.pone.0024209

Segaert, K., Menenti, L., Weber, K., Petersson, K. M., & Hagoort, P. (2012). Shared Syntax in Language Production and Language Comprehension—An fMRI Study. *Cerebral Cortex*, *22*(7), 1662–1670. https://doi.org/10.1093/cercor/bhr249

Segaert, K., Weber, K., Cladder-Micus, M., & Hagoort, P. (2014). The influence of verb-bound syntactic preferences on the processing of syntactic structures. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(5), 1448–1460. https://doi.org/10.1037/a0036796

Segaert, K., Weber, K., de Lange, F. P., Petersson, K. M., & Hagoort, P. (2013). The suppression of repetition enhancement: A review of fMRI studies. *Neuropsychologia*, *51*(1), 59–66. https://doi.org/10.1016/j.neuropsychologia.2012.11.006

Segaert, K., Wheeldon, L., & Hagoort, P. (2016). Unifying structural priming effects on syntactic choices and timing of sentence generation. *Journal of Memory and Language*. https://doi.org/10.1016/j.jml.2016.03.011

Silbert, L. J., Honey, C. J., Simony, E., Poeppel, D., & Hasson, U. (2014). Coupled neural systems underlie the production and comprehension of naturalistic narrative speech. *Proceedings of the National Academy of Sciences*, *111*(43), E4687–E4696. https://doi.org/10.1073/pnas.1323812111

Smith, M., & Wheeldon, L. (2000). Syntactic priming in spoken sentence production – an online study. *Cognition*, *78*(2), 123–164. https://doi.org/10.1016/S0010-0277(00)00110-4

Spiegelhalder, K., Ohlendorf, S., Regen, W., Feige, B., Tebartz van Elst, L., Weiller, C., … Tüscher, O. (2014). Interindividual synchronization of brain activity during live verbal communication. *Behavioural Brain Research*, *258*, 75–79. https://doi.org/10.1016/j.bbr.2013.10.015

Spreng, R. N., Mar, R. A., & Kim, A. S. N. (2008). The Common Neural Basis of Autobiographical Memory, Prospection, Navigation, Theory of Mind, and the Default Mode: A Quantitative Meta-analysis. *Journal of Cognitive Neuroscience*, *21*(3), 489–510. https://doi.org/10.1162/jocn.2008.21029

Stephens, G. J., Silbert, L. J., & Hasson, U. (2010). Speaker–listener neural coupling underlies successful communication. *Proceedings of the National Academy of Sciences*, *107*(32), 14425–14430. https://doi.org/10.1073/pnas.1008662107

Stolk, A., Noordzij, M. L., Verhagen, L., Volman, I., Schoffelen, J.-M., Oostenveld, R., … Toni, I. (2014). Cerebral coherence between communicators marks the emergence of meaning. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(51), 18183–18188. https://doi.org/10.1073/pnas.1414886111

Stolk, A., Verhagen, L., & Toni, I. (2016). Conceptual Alignment: How Brains Achieve Mutual Understanding. *Trends in Cognitive Sciences*, *20*(3), 180–191. https://doi.org/10.1016/j.tics.2015.11.007

Tannenbaum, P. H., & Williams, F. (1968). Generation of active and passive sentences as a function of subject or object focus. *Journal of Verbal Learning and Verbal Behavior*, *7*(1), 246–250. https://doi.org/10.1016/S0022-5371(68)80197-5

Thothathiri, M., & Snedeker, J. (2008). Give and take: Syntactic priming during spoken language comprehension. *Cognition*, *108*(1), 51–68. https://doi.org/10.1016/j.cognition.2007.12.012

Traxler, M. J. (n.d.). Lexically independent priming in online sentence comprehension. *Psychonomic Bulletin & Review*, *15*(1), 149–155. https://doi.org/10.3758/PBR.15.1.149

Traxler, M. J., & Tooley, K. M. (2008). Priming in sentence comprehension: Strategic or syntactic? *Language and Cognitive Processes*, *23*(5), 609–645. https://doi.org/10.1080/01690960701639898

Van Berkum, J. J. A., van den Brink, D., Tesink, C. M. J. Y., Kos, M., & Hagoort, P. (2008). The Neural Integration of Speaker and Message. *Journal of Cognitive Neuroscience*, *20*(4), 580–591. https://doi.org/10.1162/jocn.2008.20054

Verhagen, L., Dijkerman, H. C., Grol, M. J., & Toni, I. (2008). Perceptuo-Motor Interactions during Prehension Movements. *The Journal of Neuroscience*, *28*(18), 4726–4735. https://doi.org/10.1523/JNEUROSCI.0057-08.2008

Visser, M., Jefferies, E., & Lambon Ralph, M. A. (2009). Semantic Processing in the Anterior Temporal Lobes: A Meta-analysis of the Functional Neuroimaging Literature. *Journal of Cognitive Neuroscience*, *22*(6), 1083–1094. https://doi.org/10.1162/jocn.2009.21309

Weatherholtz, K., Campbell-Kibler, K., & Jaeger, T. F. (2014). Socially-mediated syntactic alignment. *Language Variation and Change*, *26*(3), 387–420. https://doi.org/10.1017/S0954394514000155

Webb, J. T. (1969). Subject Speech Rates as a Function of Interviewer Behaviour. *Language and Speech*, *12*(1), 54–67. https://doi.org/10.1177/002383096901200105

Weber, K., & Indefrey, P. (2009). Syntactic priming in German–English bilinguals during sentence comprehension. *NeuroImage*, *46*(4), 1164–1172. https://doi.org/10.1016/j.neuroimage.2009.03.040

Weissgerber, T. L., Milic, N. M., Winham, S. J., & Garovic, V. D. (2015). Beyond Bar and Line Graphs: Time for a New Data Presentation Paradigm. *PLoS Biol*, *13*(4), e1002128. https://doi.org/10.1371/journal.pbio.1002128

Wheeldon, L. R., Smith, M. C., & Apperly, I. A. (2011). Repeating words in sentences: Effects of sentence structure. *Journal of Experimental*

Psychology: Learning, Memory, and Cognition, *37*(5), 1051–1064. https://doi.org/10.1037/a0023435

Wheeldon, L., & Smith, M. (2003). Phrase structure priming: A short-lived effect. *Language and Cognitive Processes*, *18*(4), 431–442. https://doi.org/10.1080/01690960244000063

Willems, R. M., & Varley, R. (2010). Neural Insights into the Relation between Language and Communication. *Frontiers in Human Neuroscience*, *4*. https://doi.org/10.3389/fnhum.2010.00203

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*(2), 162. https://doi.org/10.1037/0033-2909.123.2.162

Samenvatting

De hele dag door krijgen je hersenen allerlei vormen van taal te verwerken. Nu bijvoorbeeld, terwijl je de samenvatting van dit proefschrift aan het lezen bent. Of als je vanavond naar het achtuurjournaal kijkt met een kopje koffie. Maar het meest nog gebruik je taal om met anderen te praten: in een gesprek of conversatie. Toch bestuderen taalonderzoekers taalproductie en taalbegrip vaak in een context die niets met conversatie te maken heeft. Dat is gek, want in een conversatie zijn er veel factoren die mogelijk van invloed kunnen zijn op de psychologische en neurale processen die taalproductie en taalbegrip mogelijk maken.

In mijn proefschrift heb ik gefocust op drie aspecten van een conversatiecontext die de taalprocessen zouden kunnen beïnvloeden. 1) Deelnemen aan een gesprek betekent niet alleen luisteren of spreken, maar luisteren én spreken. Wat je hoort beïnvloedt wat je daarna zegt en wat jij zegt beïnvloedt (je verwachtingen van) wat je daarna te horen krijgt. Hoewel taalproductie en taalbegrip vaak als individuele processen bestudeerd worden, moeten we voor een volledig begrip van hoe onze hersenen taal verwerken dus ook begrijpen hoe productie en begrip elkaar beïnvloeden. 2) Conversatie is een sociale activiteit. Afhankelijk van met wie we praten en wat voor impressie we willen achterlaten op die persoon, passen we onze spraak aan. Tegen de koningin praat je anders dan tegen je oma en met je baas praat je op een andere manier dan met je vrienden. 3) In conversatie hebben sprekers als doel om iets te communiceren. In veel taalproductie-experimenten wordt sprekers gevraagd om in een geïsoleerde ruimte, zonder enig communicatief doel plaatjes te beschrijven. Toch weten we dat sprekers hun beschrijvingen soms aanpassen aan de behoeften van hun gesprekspartner, zodat zij makkelijk kunnen begrijpen wat de spreker bedoelt. Hetzelfde nieuws wordt bijvoorbeeld anders beschreven (met andere woorden) in het jeugdjournaal dan in het late journaal.

Deze drie factoren komen samen in de experimenten die beschreven zijn in hoofdstuk 2, 3 en 4 van dit proefschrift. In deze experimenten beschrijven twee proefpersonen foto’s aan elkaar, waardoor een gecontroleerde conversatiecontext gecreëerd wordt, waarin we vervolgens bepaalde aspecten kunnen manipuleren. Een voorbeeld van een te beschrijven foto zie je hieronder (figuur S.1). Interessant aan deze foto is dat je hem op twee manieren kunt beschrijven. De meeste mensen kiezen waarschijnlijk voor *de man bedient de vrouw*, maar een andere, niet minder correcte omschrijving is *de vrouw wordt bediend door de man*. De eerste zin is een voorbeeld van een actieve zin (de bedrijvende vorm), de tweede is een passieve zin (de lijdende vorm). Uit eerdere experimenten weten we dat mensen deze plaatjes uit zichzelf meestal met een actieve zin beschrijven. Interessant is echter dat wanneer ze een passieve zin hebben gehoord bij het voorafgaande plaatje (bijvoorbeeld *de jongen wordt gekust door het meisje*), de kans groter wordt dat ze het plaatje dat volgt ook met een passieve zin beschrijven. Dit is een voorbeeld van het "syntactic priming effect". Dit effect manifesteert zich op allerlei manieren: niet alleen produceren sprekers bepaalde zinstructuren (zoals de lijdende of passieve vorm) vaker wanneer ze dezelfde structuur net gehoord (of zelf geproduceerd) hebben, ze beginnen ook sneller met spreken als ze een zinsstructuur herhalen. Uit hersenonderzoek waarin gebruik wordt gemaakt van de beeldvormingstechniek functionele MRI (fMRI) weten we bovendien dat het minder hersenactiviteit kost om een structuur te herhalen dan om deze niet te herhalen.

Figuur S.1 Een voorbeeld van de foto's die gebruikt worden in de syntactic priming experimenten in dit proefschrift. Alle fotos laten twee mensen zien (2 volwassenen of 2 kinderen, altijd één mannelijk en één vrouwelijk), en kunnen beschreven worden met een actieve zin (hier: de man bedient de vrouw) of een passieve zin (hier: de vrouw wordt bediend door de man).

Het syntactic priming effect is op zichzelf al interessant, omdat het ons vertelt dat begrip en productie van zinsstructuur (syntax) sterk aan elkaar gerelateerd zijn. Het fMRI onderzoek naar syntactic priming effecten vertelt ons bijvoorbeeld dat dezelfde hersengebieden gebruikt worden voor de productie en het begrip van zinsstructuur. Over het algemeen zijn onderzoekers het erover eens dat het grotendeels automatische mechanismes zijn die ervoor zorgen dat de productie van zinsstructuur wordt beïnvloed door de zinsstructuur die verwerkt is tijdens het luisteren (en vice versa). Verschillende theorieën suggereren echter dat syntactic priming effecten ook (deels) voort kunnen komen uit communicatieve of sociale doelen van de spreker. In hoofdstuk 2, 3 en 4 heb ik deze theorieën getest.

Als het herhalen van zinsstructuur niet alleen een automatisch effect is, maar ook een communicatief doel heeft, namelijk het vergemakkelijken van begrip voor de luisteraar, zouden syntactic priming effecten sterker moeten zijn in een communicatieve context (spreker praat tegen een partner) dan in een niet-communicatieve context (spreker heeft geen gesprekspartner en geen communicatief doel). In hoofdstuk 2 en hoofdstuk 3 heb ik de syntactic priming effecten van een groep sprekers in een communicatieve context (proefpersonen communiceren met een partner) vergeleken met de effecten gemeten in een groep sprekers die hetzelfde experiment deden zonder dat er een partner aanwezig was. Ik heb echter twee verschillende methoden gebruikt om de syntactic priming effecten te meten en gekeken naar verschillende manifestaties van het priming effect. In hoofdstuk 2 rapporteer ik de resultaten van een fMRI onderzoek waarin ik heb gekeken naar syntactic priming effecten in de hersenen (de eerste methode) en hoe snel sprekers beginnen met spreken (de tweede methode). Met deze twee methodes lieten mijn resultaten geen verschil zien in de grootte van het syntactic priming effect voor proefpersonen in een communicatieve context en proefpersonen in een non-communicatieve context. Ik vond echter wel een ander resultaat: er was een positieve correlatie tussen de grootte van het syntactic priming effect bij een proefpersoon die deel uitmaakte een paar en de grootte van het syntactic priming effect bij de andere proefpersoon van dat paar. Als de één groot effect liet zien, dan de ander ook; als de één een klein effect liet zien, dan de ander ook. Echter, in een tweede studie (hoofdstuk 2B) hebben we deze correlatie niet kunnen repliceren.

Omdat het opnieuw kunnen aantonen van een effect in een andere steekproef van dezelfde populatie (een andere groep proefpersonen) belangrijk is voor de validiteit van onderzoeksresultaten, kunnen we geen sterke conclusies verbinden aan de gevonden correlatie in hoofdstuk 2. Het zou een toevallige bevinding kunnen zijn die niet generaliseerbaar is naar de werkelijkheid.

In hoofdstuk 3 heb ik syntactic priming effecten gemeten in de keuzes van sprekers tussen twee alternatieve zinstructuren (een derde mogelijkheid om het syntactic priming effect te kwantificeren). Hoewel we ervan uitgaan dat syntactic priming effecten in het brein, in reactietijden en in de spekers keuzes tussen structurele alternatieven allen resultaten zijn van hetzelfde mechanisme, zou het kunnen zijn dat het effect van communicatieve/sociale doelen van de spreker sterker is in paradigma's waarin de spreker vrij is om zelf te kiezen voor een zinsstructuur. En inderdaad, het belangrijkste resultaat in hoofdstuk 3 was dat sprekers de zinsstructuren van hun partners vaker herhaalden in de communicatieve context dan in de non-communicatieve context. Zoals besproken in het discussie hoofdstuk van dit proefschrift, zijn er twee mogelijke redenen dat we een effect vinden van het hebben van een gesprekspartner in hoofdstuk 3, maar niet in hoofdstuk 2. Een van die redenen is dat sociale, communicatieve doelen (zoals het willen vergemakkelijken van begrip voor de luisteraar) geen direct effect hebben op het syntactic priming effect zelf, maar in plaats daarvan samen met het priming effect een effect hebben op de keuze van de spreker voor een bepaalde zinsstructuur.

Het experiment dat ik heb opgeschreven in hoofdstuk 4 focust niet zozeer op het doel van de spreker om te communiceren, maar test de hypothese dat syntactic priming effecten (deels) gedreven worden door sociale doelen. Als dit zo is, zouden sprekers een zinsstructuur vaker moeten herhalen als ze een goede indruk op hun gesprekspartner willen maken. Ik heb het syntactic priming effect (gemeten in keuzes tussen structurele alternatieven) vergeleken van proefpersonen die wisten dat ze beoordeeld zouden worden door hun partner, proefpersonen die wisten dat ze beoordeeld werden en die daarnaast verteld werd dat ze een positieve indruk moesten maken op hun partner en proefpersonen die niet wisten dat ze beoordeeld zouden worden door hun partner. We vonden echter geen verschil in de grootte van het syntactic priming effect tussen deze drie groepen. Bovendien vonden we ook geen overtuigend bewijs dat het herhalen van zinsstructuur een effect heeft op hoe de spreker eigenlijk beoordeeld werd. Het lijkt er dus op dat het doel van de spreker om een positieve indruk te maken op de luisteraar niet hetzelfde effect heeft op het herhalen van zinsstructuur als het doel van de spreker om begrip te vergemakkelijken voor de luisteraar.

In hoofdstuk 5 en 6 onderzoek ik communicatie als een doel op zich, niet hoe het andere taalverwerkingsprocessen zou kunnen beïnvloeden. Hoewel succesvolle communicatie erg belangrijk is in ons leven, weten we maar weinig over hoe communicatief succes gereflecteerd wordt in ons brein. In hoofdstuk 5 en 6 focus ik op een vrij nieuwe benadering van hersenonderzoek naar communicatie: de multi-brein benadering. Dit betekent dat we hersenactiviteit meten van twee (of meer) personen in een interactie (bijvoorbeeld de spreker en de luisteraar) en dat we kijken hoe de hersenactiviteit van de één aan de activiteit van de ander gerelateerd is. Hoofdstuk 5 is een theoretisch hoofdstuk waarin ik uitleg hoe de multi-brein benadering gebruikt zou kunnen worden in hersenonderzoek naar talige communicatie. Op basis van een eerder voorstel door de onderzoekers Friston en Frith, formuleer ik de hypothese dat succesvolle communicatie gereflecteerd zou kunnen worden in correlaties in breinactiviteit tussen spreker en luisteraar, in hersengebieden die van belang zijn voor mentale representatie van het onderwerp van discussie. Deze hypothese heb ik vervolgens getest in hoofdstuk 6. Sprekers beschreven een plattegrond van een dierentuin, terwijl hun hersenactiviteit gemeten werd in de MRI-scanner. Die beschrijving werd opgenomen en later afgespeeld voor een luisteraar, terwijl we ook bij de luisteraar de hersenactiviteit hebben gemeten. De resultaten van dit onderzoek laten zien dat het beschrijven en interpreteren van een plattegrond leidt tot correlaties in hersenactiviteit over tijd in verschillende hersengebieden die belangrijk zijn voor deze processen. Bovendien waren spreker-luisteraar correlaties in een bepaald hersengebied in de linker hersenhelft (ventrale precuneus) sterker wanneer de communicatie tussen spreker en luisteraar succesvoller was.

Samenvattend kan gezegd worden dat het werk in dit proefschrift nieuwe deuren opent naar taalonderzoek in een sociale, communicatieve, conversatiecontext. De experimenten in dit proefschrift laten zien dat gecontroleerde, systematische manipulaties mogelijk zijn in een context waarin proefpersonen communiceren met een partner. Bovendien benadrukken de resultaten van mijn onderzoek dat de relatie tussen taal en communicatie, zoals in een conversatie, alleen begrepen kan worden door beide aspecten in overweging te nemen.

Acknowledgements

I first walked through the doors of the MPI in 2012. Now, three stolen bikes, four Christmas parties and five journal submissions later, I have completed my PhD dissertation. Of course, I couldn't have done this alone.

First, I would like to thank the people that have provided me with the opportunity to get to where I am now. Peter, you have provided me with everything I needed to become an independent researcher and I am proud to have worked with you. Katrien, working with you always felt like being part of a team, rather than working for a boss. You and Peter trusted me enough to be responsible for my own projects, with you there to provide the necessary guidance, motivation and support. You are a wonderful supervisor who has always been there for me. Even when you moved to the UK, I have never felt like I was on my own. You just made sure that Evelien and I could come visit you (also thank you Ali & Ono for providing a home away from home!). I would like to thank you for teaching me to always celebrate victories, little as they may be. And when there weren't any victories to celebrate, thank you for reminding me that there is more to life than p-values. Laura, although we only worked together for a brief period of time, you were the one who initially offered me a place at the MPI to do my research internship. Thank you for that, and for finding me a great alternative supervisor when you left!

I would also like to thank my reading committee, Prof. Antje Meyer, Prof. Emiel Krahmer and Dr. Roel Willems. Thank you for taking the time to read and evaluate my dissertation. And to Evelien & Geertje, my paranimphs: thank you for being there for me during my defense, but especially for making working on the dissertation so much more pleasant than it could have been.

A big thanks to all the people in the NBL department, for your help (especially Kirsten & Alexis), feedback and ideas. To all MPI-based NBL people, I can never thank you enough for adapting to my crazy early lunch preferences and having lunch with me (almost) every day! It was much appreciated! I would like to thank a few people in particular. Evelien & Gwilym, I will miss our morning coffees, your discussions about an enormous variety of random things and your infinite supply of bizarre youtube videos to take our minds off all things not nice about being a PhD. Evelien, thank you for hosting so many wonderful dinners and game nights (also thank you Job!), for being great company during many many train rides, flights to Bham and back, and for working with me on Lottelien. Ina, even when I'd had a horrible morning because I had to bike through the rain and my train was delayed, seeing you always cheered me up! Thanks for being such a great secretary and above all, a wonderful person. Bohan, I am very happy I got to share an office with you! Geertje & Monique, thanks for being lekker nuchter yet super snobby drinking pink champagne on a rooftop terrace in Malta! Franziska, thanks for being a fantastic storyteller, and for sharing a fancy hotelroom with me in London. Jolien, thanks for trusting me with the NBL websites and for teaching me a lot about science communication. And thanks to Charlotte, Anne, Nadine & Tineke, for all your help: you were the best research assistants ever.

I'd like Thea & Maud for great lunches and keeping me up to date with MPI gossip. Amie, Johanne, Lisa, Annika, Suzanne: thanks for the coffees, teas, beers & wines, our chats about work and everything else. Els & Dirkje, the IMPRS and the MPI, thank you for providing us with the opportunity to organize our own conference and de Taalmiddag. I have learned so much from this that I would never have learned if I had only been working on my research projects. Also thanks to Lisa and the rest of the team for making this a great experience!

Last but not least, I would like to thank the people who have nothing to do with work, but who have played an essential role in finishing this dissertation, because they make me very happy: dankjewel lieve vrienden, familie, schoonfamilie en carnavalsfamilie. Dankjewel papa & mama voor altijd onvoorwaardelijk trots zijn op mij. En natuurlijk dankjewel Jeroen, mijn liefste, dankjewel dat je er altijd voor mij bent en altijd in mij gelooft.

Curriculum Vitae

Lotte Schoot was born in 1990 in ‘s-Hertogenbosch, The Netherlands. She obtained her bacherlor’s degree in Linguistics from Utrecht University (2011), after which she completed the Research Master Language & Cognition at the University of Groningen in 2013 (cum laude). She then started as a PhD student in the Neurobiology of Language department of the Max Planck Institute for Psycholinguistics, to carry out the work that was described in this thesis. Currently, Lotte is a Research Fellow at the Department of Psychiatry at Massachusetts General Hospital and Harvard Medical School, Boston, USA.

Publications

Schoot, L., Hagoort, P., & Segaert, K. (2016). What can we learn from a two-brain approach to verbal interaction? Neuroscience and Biobehavioral Reviews,68, 454-459. doi:10.1016/j.neubiorev.2016.06.009.

Schoot, L., Heyselaar, E., Hagoort, P., & Segaert, K. (2016). Does syntactic alignment effectively influence how speakers are perceived by their conversation partner. PLoS One, 11(4): e015352. doi:10.1371/journal.pone.0153521.

Schoot, L., Menenti, L., Hagoort, P., & Segaert, K. (2014). A little more conversation - The influence of communicative context on syntactic priming in brain and behavior. Frontiers in Psychology, 5: 208. doi:10.3389/fpsyg.2014.00208.

MPI Series in Psycholinguistics

1. The electrophysiology of speaking: Investigations on the time course of semantic, syntactic, and phonological processing. *Miranda van Turennout*
2. The role of the syllable in speech production: Evidence from lexical statistics, metalinguistics, masked priming, and electromagnetic midsagittal articulography. *Niels O. Schiller*
3. Lexical access in the production of ellipsis and pronouns. *Bernadette M. Schmitt*
4. The open-/closed-class distinction in spoken-word recognition. *Alette Haveman*
5. The acquisition of phonetic categories in young infants: A self-organising artificial neural network approach. *Kay Behnke*
6. Gesture and speech production. *Jan-Peter de Ruiter*
7. Comparative intonational phonology: English and German. *Esther Grabe*
8. Finiteness in adult and child German. *Ingeborg Lasser*
9. Language input for word discovery. *Joost van de Weijer*
10. Inherent complement verbs revisited: Towards an understanding of argument structure in Ewe. *James Essegbey*
11. Producing past and plural inflections. *Dirk Janssen*
12. Valence and transitivity in Saliba: An Oceanic language of Papua New Guinea. *Anna Margetts*
13. From speech to words. *Arie van der Lugt*
14. Simple and complex verbs in Jaminjung: A study of event categorisation in an Australian language. *Eva Schultze-Berndt*
15. Interpreting indefinites: An experimental study of children's language comprehension. *Irene Krämer*
16. Language-specific listening: The case of phonetic sequences. *Andrea Weber*
17. Moving eyes and naming objects. *Femke van der Meulen*
18. Analogy in morphology: The selection of linking elements in Dutch compounds. *Andrea Krott*
19. Morphology in speech comprehension. *Kerstin Mauth*

20. Morphological families in the mental lexicon. *Nivja H. de Jong*
21. Fixed expressions and the production of idioms. *Simone A. Sprenger*
22. The grammatical coding of postural semantics in Goemai (a West Chadic language of Nigeria). *Birgit Hellwig*
23. Paradigmatic structures in morphological processing: Computational and cross-linguistic experimental studies. *Fermín Moscoso del Prado Martín*
24. Contextual influences on spoken-word processing: An electrophysiological approach. *Daniëlle van den Brink*
25. Perceptual relevance of prevoicing in Dutch. *Petra M. van Alphen*
26. Syllables in speech production: Effects of syllable preparation and syllable frequency. *Joana Cholin*
27. Producing complex spoken numerals for time and space. *Marjolein Meeuwissen*
28. Morphology in auditory lexical processing: Sensitivity to fine phonetic detail and insensitivity to suffix reduction. *Rachèl J. J. K. Kemps*
29. At the same time...: The expression of simultaneity in learner varieties. *Barbara Schmiedtová*
30. A grammar of Jalonke argument structure. *Friederike Lüpke*
31. Agrammatic comprehension: An electrophysiological approach. *Marlies Wassenaar*
32. The structure and use of shape-based noun classes in Miraña (North West Amazon). *Frank Seifart*
33. Prosodically-conditioned detail in the recognition of spoken words. *Anne Pier Salverda*
34. Phonetic and lexical processing in a second language. *Mirjam Broersma*
35. Retrieving semantic and syntactic word properties. *Oliver Müller*
36. Lexically-guided perceptual learning in speech processing. *Frank Eisner*
37. Sensitivity to detailed acoustic information in word recognition. *Keren B. Shatzman*
38. The relationship between spoken word production and comprehension. *Rebecca Özdemir*
39. Disfluency: Interrupting speech and gesture. *Mandana Seyfeddinipur*

40. The acquisition of phonological structure: Distinguishing contrastive from non-contrastive variation. *Christiane Dietrich*
41. Cognitive cladistics and the relativity of spatial cognition. *Daniel B.M. Haun*
42. The acquisition of auditory categories. *Martijn Goudbeek*
43. Affix reduction in spoken Dutch. *Mark Pluymaekers*
44. Continuous-speech segmentation at the beginning of language acquisition: Electrophysiological evidence. *Valesca Kooijman*
45. Space and iconicity in German Sign Language (DGS). *Pamela Perniss*
46. On the production of morphologically complex words with special attention to effects of frequency. *Heidrun Bien*
47. Crosslinguistic influence in first and second languages: Convergence in speech and gesture. *Amanda Brown*
48. The acquisition of verb compounding in Mandarin Chinese. *Jidong Chen*
49. Phoneme inventories and patterns of speech sound perception. *Anita Wagner*
50. Lexical processing of morphologically complex words: An information-theoretical perspective. *Victor Kuperman*
51. A grammar of Savosavo, a Papuan language of the Solomon Islands. *Claudia Wegener*
52. Prosodic structure in speech production and perception. *Claudia Kuzla*
53. The acquisition of finiteness by Turkish learners of German and Turkish learners of French: Investigating knowledge of forms and functions in production and comprehension. *Sarah Schimke*
54. Studies on intonation and information structure in child and adult German. *Laura de Ruiter*
55. Processing the fine temporal structure of spoken words. *Eva Reinisch*
56. Semantics and (ir)regular inflection in morphological processing. *Wieke Tabak*
57. Processing strongly reduced forms in casual speech. *Susanne Brouwer*
58. Ambiguous pronoun resolution in L1 and L2 German and Dutch. *Miriam Ellert*

59. Lexical interactions in non-native speech comprehension: Evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging. *Ian FitzPatrick*
60. Processing casual speech in native and non-native language. *Annelie Tuinman*
61. Split intransitivity in Rotokas, a Papuan language of Bougainville. *Stuart Robinson*
62. Evidentiality and intersubjectivity in Yurakaré: An interactional account. *Sonja Gipper*
63. The influence of information structure on language comprehension: A neurocognitive perspective. *Lin Wang*
64. The meaning and use of ideophones in Siwu. *Mark Dingemanse*
65. The role of acoustic detail and context in the comprehension of reduced pronunciation variants. *Marco van de Ven*
66. Speech reduction in spontaneous French and Spanish. *Francisco Torreira*
67. The relevance of early word recognition: Insights from the infant brain. *Caroline Junge*
68. Adjusting to different speakers: Extrinsic normalization in vowel perception. *Matthias J. Sjerps*
69. Structuring language. Contributions to the neurocognition of syntax. *Katrien R. Segaert*
70. Infants' appreciation of others' mental states in prelinguistic communication: A second person approach to mindreading. *Birgit Knudsen*
71. Gaze behavior in face-to-face interaction. *Federico Rossano*
72. Sign-spatiality in Kata Kolok: how a village sign language of Bali inscribes its signing space**.** *Conny de Vos*
73. Who is talking? Behavioural and neural evidence for norm-based coding in voice identity learning. *Attila Andics*
74. Lexical processing of foreign-accented speech: Rapid and flexible adaptation. *Marijt Witteman*
75. The use of deictic versus representational gestures in infancy. *Daniel Puccini*

76. Territories of knowledge in Japanese conversation. *Kaoru Hayano*
77. Family and neighbourhood relations in the mental lexicon: A cross-language perspective. *Kimberley Mulder*
78. Contributions of executive control to individual differences in word production. *Zeshu Shao*
79. Hearing speech and seeing speech: Perceptual adjustments in auditory-visual processing. *Patrick van der Zande*
80. High pitches and thick voices: The role of language in space-pitch associations. *Sarah Dolscheid*
81. Seeing what's next: Processing and anticipating language referring to objects. *Joost Rommers*
82. Mental representation and processing of reduced words in casual speech. *Iris Hanique*
83. The many ways listeners adapt to reductions in casual speech. *Katja Poellmann*
84. Contrasting opposite polarity in Germanic and Romance languages: Verum Focus and affirmative particles in native speakers and advanced L2 learners. *Giuseppina Turco*
85. Morphological processing in younger and older people: Evidence for flexible dual-route access. *Jana Reifegerste*
86. Semantic and syntactic constraints on the production of subject-verb agreement. *Alma Veenstra*
87. The acquisition of morphophonological alternations across languages. *Helen Buckler*
88. The evolutionary dynamics of motion event encoding. *Annemarie Verkerk*
89. Rediscovering a forgotten language. *Jiyoun Choi*
90. The road to native listening: Language-general perception, language-specific input. *Sho Tsuji*
91. Infants'understanding of communication as participants and observers. *Gudmundur Bjarki Thorgrímsson*
92. Information structure in Avatime. *Saskia van Putten*
93. Switch reference in Whitesands. *Jeremy Hammond*

94. Machine learning for gesture recognition from videos. *Binyam Gebrekidan Gebre*
95. Acquisition of spatial language by signing and speaking children: a comparison of Turkish sign language (TID) and Turkish. *Beyza Sümer*
96. An ear for pitch: on the effects of experience and aptitude in processing pitch in language and music. *Salomi Savvatia Asaridou*
97. lncrementality and Flexibility in Sentence Production. *Maartje van de Velde*
98. Social learning dynamics in chimpanzees: Reflections on (nonhuman) animal culture. *Edwin van Leeuwen*
99. The request system in Italian interaction. *Giovanni Rossi*
100. Timing turns in conversation: A temporal preparation account. *Lilla Magyari*
101. Assessing birth language memory in young adoptees. *Wencui Zhou*
102. A social and neurobiological approach to pointing in speech and gesture. *David Peeters*
103. Investigating the genetic basis of reading and language skills. *Alessandro Gialluisi*
104. Conversation Electrified: The Electrophysiology of Spoken Speech Act Recognition. *Rósa Signý Gisladottir*
105. Modelling Multimodal Language Processing. *Alastair Smith*
106. Predicting language in different contexts: The nature and limits of mechanisms in anticipatory language processing. *Florian Hintz*
107. Situational variation in non-native communication. *Huib Kouwenhoven*
108. Sustained attention in language production. *Suzanne Jongman*
109. Acoustic reduction in spoken-word processing: Distributional, syntactic, morphosyntatic, and orthographic effects. *Malte Viebahn*
110. Nativeness, dominance, and the flexibility of listening to spoken language. *Laurence Bruggeman*
111. Semantic specificity of perception verbs in Maniq. *Ewelina Wnuk*
112. On the identification of FOXP2 gene enhancers and their role in brain development. *Martin Becker*

113. Events in language and thought: The case of serial verb constructions in Avatime. *Rebecca Defina*

114. Deciphering common and rare genetic effects on reading ability. *Amaia Carrión Castillo*

115. Music and language comprehension in the brain. *Richard Kunert*

116. Comprehending Comprehension: Insights from neuronal oscillations on the neuronal basis of language. *Nietzsche H.L. Lam*

117. The biology of variation in anatomical brain asymmetries. *Tulio Guadalupe*

118. Language processing in a conversation context. *Lotte Schoot*