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Communication beyond Form: How the Brain Processes Communicative Intention

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Contents

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Abstract

One of the most useful tools in the service of communication is language. However, the neuro-cognitive basis of language has often been studied outside of its natural niche and in isolation from its communicative function. This thesis examines the neuro-cognitive processes that are at the basis of processing communicative intention conveyed by language by employing a range of psycho- and neurolinguistic methods.

In particular, the present work focuses on two pragmatic phenomena: speech acts and indirect speech acts. The following questions are asked: (1) Can the differences in neural signatures of speech acts previously observed in the comprehension modality also be found in speech production? (2) Is the right temporo-parietal junction, an important node of the ToM network, *causally* involved in the comprehension of indirect speech acts? (3) Do indirect speech acts systematically differ from direct ones in psycholinguistic properties, whose processing is known to be reflected in different neural processes? The general methodological approach taken here is to use identical words or sentences but alter their pragmatic-communicative roles by embedding them in different dialogic or situational contexts. This way, the communicative function can be examined independently from the linguistic form used to carry it out.

In a first study, the neural representations of *naming* and *request* actions were examined. These were performed using the same utterance during speech production, while subjects participated in an interactive communicative task and while participants neural activity was recorded by electroencephalography. The aim was to compare these findings to previous findings in the comprehension modalities. We find that uttering the same words with different speech act functions (*naming* and *request*) is associated with different electrophysiological signatures. These differences are similar to those found when comparing the same two speech acts in the comprehension modality. In particular, *requests* are associated with activations of the motor system, supporting the idea that their intrinsic link to action is also encoded in the brain.

The second study tested whether the comprehension of indirect speech acts relies on the right-temporoparietal junction, a brain region thought to contribute to Theory of Mind processes. To do so, activity in these brain regions was altered

by means of (non-invasive) transcranial magnetic stimulation. Subjects were then exposed to indirect speech acts and their matched direct controls, and their comprehension processes were behaviorally monitored. The finding that comprehending indirect speech acts is more costly than comprehending direct ones was replicated. Applying TMS to the right-temporoparietal junction did not affect the processing of indirect speech acts when these were matched to their direct controls in terms of communicative function. However, the speed of comprehension of indirect speech acts was altered relative to the direct controls when they were not matched for communicative function.

In a third study, subjects were asked to provide ratings of several psycholinguistic dimensions for both direct and indirect speech acts to assess the differences between them. Compared to their direct counterparts, indirect speech acts were found to be less predictable, less coherent with their context, less semantically related to their context, and understood with less certainty. Notably, these properties were tightly related to the in/directness of the stimuli.

In summary, it could be shown that (i) communicative function can be encoded in the brain in ways that are similar between comprehension and production modality, (ii) specificities of the neural representations of speech acts can be related to their use in communication, (iii) there was no evidence of the right-temporoparietal junction processing indirect speech acts when compared to well-matched controls, and (iv) contrasting direct and indirect speech acts revealed several differences unrelated to ToM that suggest the (additional) contribution of other brain systems in the comprehension of indirect speech acts. Overall, it was demonstrated that when identical utterances are used with different communicative functions—whether direct or indirect—are associated with different neurocognitive processes. These findings add to the growing literature examining the communicative function of language and argue for greater inclusion of pragmatics in neurocognitive models of language function.

Zusammenfassung

Eines der nützlichsten Werkzeuge, um erfolgreich zu kommunizieren, ist die Sprache. Dennoch wurden die neurokognitiven Grundlagen der Sprache oft außerhalb ihres natürlichen Kontexts und isoliert von ihrer kommunikativen Funktion untersucht. In der vorliegenden Arbeit werden die neurokognitiven Prozesse analysiert, die der Verarbeitung von kommunikativen Intentionen, die durch die Sprache vermittelt werden, zugrunde liegen. Dafür wird eine Reihe von psycho- und neurolinguistischen Methoden eingesetzt. Der Fokus liegt insbesondere auf zwei pragmatische Phänomene: Sprechakte und indirekte Sprechakte. Zu diesem Thema werden folgende Fragen gestellt: (1) Lassen sich die Unterschiede in den neuronalen Aktivitätsmuster von Sprechakten, die zuvor in der Verstehensmodalität beobachtet wurden, auch in der Sprachproduktion finden? (2) Ist die rechte temporoparietale Verbindung, ein wichtiger Knotenpunkt des ToM-Netzwerks, kausal am Verstehen indirekter Sprechakte beteiligt? (3) Gibt es systematische Unterschiede zwischen indirekten und direkten Sprechakten in Bezug auf ihre psycholinguistischen Eigenschaften, deren Verarbeitung sich bekanntermaßen in unterschiedlichen neuronalen Prozessen widerspiegelt? Um diese Frage zu beantworten, werden identische Wörter und Sätze verwendet, aber ihre pragmatisch-kommunikativen Rollen verändert, indem beide in unterschiedliche dialogische oder situative Kontexte eingebettet werden. Auf diese Weise kann die kommunikative Funktion unabhängig von der sprachlichen Form, mit der sie ausgeführt wird, untersucht werden. In einer ersten Studie wurden die neuronalen Repräsentationen von *Benennungs-* und *Aufforderungs*handlungen untersucht. Diese wurden mittels der gleichen Äußerung während der Sprachproduktion durch Elektroenzephalographie aufgezeichnet, während die ProbandInnen an einer interaktiven kommunikativen Aufgabe teilnahmen. Dank dieser Studie konnte man feststellen, dass die Äußerung der gleichen Wörter mit unterschiedlichen Sprechaktfunktionen (*Benennen* und *Auffordern*) mit unterschiedlichen elektrophysiologischen Aktivitätsmuster verbunden ist. Diese Unterschiede ähneln denen, die beim Vergleich dieser beiden Sprechakte zuvor bereits in der Verstehensmodalität gefunden wurden. Besonders deutlich zeigte sich, dass *Aufforderungen* mit Aktivierungen des motorischen Systems verbunden sind, was darauf hindeutet, dass ihre intrinsische Verbindung zur Handlung im Gehirn kodiert wird. In der

zweiten Studie wurde untersucht, ob das Verstehen indirekter Sprechakte von der rechts-temporoparietalen Verbindung abhängt, einer Hirnregion, von der angenommen wird, dass sie zu Theory of Mind-Prozessen beiträgt. Zu diesem Zweck wurde die Aktivität in dieser Hirnregion durch (nicht-invasive) transkranielle Magnetstimulation verändert. Die Versuchspersonen wurden dann indirekten Sprachhandlungen und den gematchten direkten Kontrollstimuli ausgesetzt und ihre Verstehensprozesse wurden beobachtet. Das Ergebnis, dass das Verstehen indirekter Sprachhandlungen aufwendiger ist als das Verstehen direkter Sprachhandlungen, wurde repliziert. Die Anwendung von TMS an der rechts-temporoparietalen Verbindung hatte keinen Einfluss auf die Verarbeitung von indirekten Sprechakten, wenn diese in Bezug auf die kommunikative Funktion auch mit den direkten Kontrollstimuli übereinstimmten. Die Geschwindigkeit des Verstehens indirekter Sprechakte war jedoch im Vergleich zu den direkten verändert, wenn diese nicht die gleiche kommunikative Funktion hatten.

In einer dritten Studie wurden die ProbandInnen gebeten, verschiedene psycholinguistische Eigenschaften sowohl für direkte als auch für indirekte Sprechakte zu bewerten, um die Unterschiede zwischen ihnen zu beurteilen. Im Vergleich zu ihren direkten Pendants erwiesen sich indirekte Sprechakte als weniger vorhersehbar, weniger kohärent mit ihrem Kontext, weniger semantisch in ihren Kontext eingebunden und weniger sicher verstehbar. Bemerkenswert ist, dass diese Eigenschaften in engem Zusammenhang mit der In/Direktheit der Stimuli standen.

Zusammenfassend konnte gezeigt werden, dass (i) die kommunikative Funktion für die Verstehens- und die Produktionsmodalität im Gehirn ähnlich kodiert ist, (ii) die Besonderheiten der neuronalen Repräsentationen von Sprechakten mit ihrer Verwendung in der Kommunikation zusammenhängen, (iii) es, wenn zu einer adäquaten Kontrollbedingung verglichen, keine Hinweise darauf gibt, dass die rechts-temporoparietale Verbindung indirekte Sprechakte verarbeitet, und (iv) die Gegenüberstellung von direkten und indirekten Sprechakten verschiedene Unterschiede aufzeigte, die nicht mit ToM in Verbindung stehen, was auf den (zusätzlichen) Beitrag anderer Gehirnsysteme beim Verstehen indirekter Sprechakte hindeutet. Insgesamt konnte gezeigt werden, dass identische Äußerungen mit unterschiedlichen kommunikativen Funktionen, seien sie nun direkt oder indirekt, mit unterschiedlichen neurokognitiven Prozessen einhergehen. Diese Ergebnisse ergänzen die wachsende Literatur, die die kommunikative Funktion von Sprache untersucht und liefern Argumente dafür, Pragmatik mehr in neurokognitive Modelle von Sprachfunktion einzubeziehen.

List of Publications

Published

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Submitted

Boux, I. & Pulvermüller, F. (submitted). Does the right temporo-parietal junction play a role in processing indirect speech acts? A transcranial magnetic stimulation study.

Abbreviations and terminology

+>	implicate
(rm)ANOVA	(repeated measures) analysis of variance
APT	action perception theory
a.u.	arbitrary units
BWLG Model	Broca–Wernicke–Lichtheim–Geschwind model
CG	common ground
LMM	linear mixed models
EEG	electroencephalogram
(v/h)EOG	(vertical/horizontal) electro-oculogram
ERP	event-related potential
fMRI	functional magnetic resonance imaging
F0	fundamental frequency
FTA	face threatening act
H	hearer
HNR	harmonics-to-noise ratio
ISA	indirect speech acts
(l/r)IFG	(left/right) inferior frontal gyrus
LSA	latent semantic analysis
(l/r)MTG	(left/right) middle temporal gyrus
M	mean
(l/r)M1	primary motor cortex
MEG	magnetoencephalogram
mPFC	medial prefrontal cortex
(l/r)MTG	middle temporal gyrus
RMT	resting motor threshold
SD	standard deviation
SEM	standard error of the mean
(l/r)SMA	supplementary motor area
PCA	principal component analysis
(l/r)PreCun	precuneus
RMS	root mean square

RP	readiness potential
S	speaker
SA	speech act
(p)STS	(posterior) superior temporal sulcus
TAPCo	theory of action prediction in communication
(r)TMS	(repetitive) transcrainal magnetic stimulation
ToM	Theory of Mind
(l/r)TPJ	(left/right) temporo-parietal junction
VO	voice onset

Terminology *précis*

In the present work, the expression "speech *comprehension*" is used to encompass all aspects of the processing of an incoming linguistic signal (phonological, lexical, syntactical, semantic, pragmatics), not just semantic aspects thereof. It is opposed to the expression "speech *production*", which in turn refers to all aspects of the processing of an outgoing linguistic signal.

The expression "speech act *type*" refers to the variability of communicative functions or illocutionary forces in communication (e.g., *requests*, *warnings*, *wishes*, *promises*, *offers*, etc.) regardless of whether these are carried out directly or indirectly.

Chapter 1

General Introduction

Human communication allows us to transmit knowledge, share feelings, create and maintain social ties, and cooperate in incredibly complex ways. It is difficult to imagine how human civilization as we know it could have come to be without the finest communicative abilities. One of the most useful tools in the service of communication is language, a uniquely human faculty that allows us to achieve these goals by using symbols and combining them in a rule-based manner to form novel expressions. Recent approaches to the study of language have expanded their focus from the exclusive study of structural aspects of language to include aspects of language use in communication. These have emphasized language as a means to share and recognize intentions. Indeed, a speaker produces an utterance with a specific communicative intention, while the hearer's task is not only to understand the utterance but, crucially, to understand the speaker's intentions in uttering it (Grice, 1957). Nevertheless, to date, the neuro-cognitive processes underlying communication on both the speaker and hearer sides are poorly understood, and language as a function of its communicative purpose is rarely studied from a neurolinguistic perspective. The goal of this thesis is to contribute to elucidating such processes, with a focus on the phenomena of speech acts and indirect speech acts.

The Introduction (Chapter 1) is dedicated to characterizing the object of study and the state of the art in neurolinguistic research. First, in Section 1.1, I introduce the idea of language as a tool for communication. Next, in Section 1.2, I describe the notion of speech acts and indirect speech acts to illustrate the phenomenon of interest; the characterization of these phenomena at the theoretical and linguistic level allows us to make predictions concerning the neural underpinnings of these phenomena. In Section 1.3, I report on the state of the art of neurolinguistic research on these two pragmatic phenomena and how they relate to general neurobiological models of language processing. Finally, in Section 1.4, I more narrowly define the goals of this dissertation. The introductory chapter will be followed by Chapters 2, 3 and 4, each reporting on individual studies on the neural correlates of speech acts and indirect speech acts. This dissertation continues with a general discussion in Chapter 5, where the outcomes of the three studies are first individually summarized in Section 5.1 and their contributions to the understanding of the neural basis of pragmatic and language processing are discussed in Section 5.2. This section is followed by a discussion of the outlooks and limitations of the approach taken throughout this work in Section 5.3 and by the final conclusion in Section 5.4.

1.1 Language in use

The words and sentences that make up language, can be described at their structural level. The various sub-specializations of linguistics focus on different aspects thereof, from their acoustic and phonological structure to the inner structure of words and sentences and their meaning. However, an additional level of analysis is concerned with how linguistic structures are used for their communicative purposes in the context of linguistic interaction.

From a philosophical perspective, language has been seen as the philosopher's instrument to describe and debate the world. Therefore, much effort was dedicated to determining the correspondence between reality and what is expressed by means of language. Already in antiquity, St. Augustine described the process of acquiring language as essentially the process of learning the association between a given word and its referent (Augustine, 1876, I. 8.). Therefore, a child would learn that a certain object in the world is called a certain way because adults in their surroundings repeatedly use a specific expression to refer to it. Moving from single words to sentences, according to Frege (1892), knowing the reference of a sentence means knowing its truth conditions, that is, knowing under which condition the sentence can be evaluated to be true or false. In a similar vein, much interest was dedicated to determining the truth conditions of sentences that appear defective such as "The present king of France is bold", when no such figure exists any longer (Russell, 1905). However, many expressions used in natural, ordinary language are ambiguous, vague, and imprecise, so that their relation to the world and to truth cannot be easily established. For instance, Russell eventually dismissed natural language because of its ambiguities, vagueness, and imperfection, which make its relation to reality unclear. Instead, he proposed the use of ideal formal languages as better tools to describe the world for philosophical purposes (Russell, 1931).

This tendency to focus on correspondences between the world and what is conveyed by means of language was then challenged by the later Wittgenstein. In his *Philosophical Investigations* Wittgenstein (1953) criticized his predecessors for having an overly narrow view of the functions of language and claimed that the descriptive function was only one of the many uses one could make of language. In his view, language was tightly bound to language-games, that is, the context of the activities for which language is used.

> *"[...] the term* "language-game" *is meant to bring into prominence the fact that the* speaking *of a language is part of an activity, or of a form of life."* - Ludwig Wittgenstein, 1953, Philosophical Investigations, §22 (emphasis in original)

Wittgenstein compared language use to a game such as chess. In his analogy, linguistic expressions are comparable to the pieces of chess. They can be used to perform "moves" in the game. In other words, linguistic expressions are tools to perform communicative actions. In addition, if a game such as chess is typically governed by rules, so is a language-game, so that language use is subject to rules of convention that are proper to any given community of speakers and to any language-game. Therefore, he argued that the meaning of a word (or other expression) is its use in a language game.

> *"For a* large *class of cases - though not for all - in which we employ the word "meaning" it can be defined thus: the meaning of a word is its use in a language. And the* meaning *of a name is sometimes explained by pointing to its* bearer." - Ludwig Wittgenstein, 1953, Philosophical Investigations, §43 (emphasis in original)

More recently, other scholars have also stressed the intentional and social dimensions of linguistic behavior. For instance, Grice (1957) argued for a distinction between two types of meanings. *Natural* meaning ($meaning_N$), as in, e.g., "These spots mean measles", relates to the fact that one can recognize a natural causality between entities or facts, so that the spots are a consequence of measles and therefore an indicator thereof. Most of the meaning conveyed by linguistic means is, however, *nonnatural* meaning ($meaning_{NN}$), e.g., "Those three rings on the bell (of the bus) mean that the bus is full" or "Smith couldn't get on without his trouble and strife", meant that Smith found his wife indispensable (examples are taken from Grice, 1957). The key distinction between meaning$_N$ and meaning$_{NN}$ is intentionality. That is, according to Grice, saying that A means$_{NN}$ something is equivalent to saying that *"A intended the utterance of x to produce some effect on the audience by means of the recognition of his intention*". The speaker, therefore, has the intention to communicate something, which in turn must be recognized by the hearer. In addition to these definitions of meaning, Grice also pointed out that communicative behavior can be considered a form of cooperative behavior (Grice, 1975). Similarly, Clark argued that using language, similar to dancing or playing in an orchestra, is a form of *joint action.* This means that communicating by means of language is not only a matter of two (or more) people exhibiting linguistic behavior on their own; in addition, their linguistic behavior needs to be coordinated (Clark, 1996), again emphasizing the interactional and interpersonal dimensions of language use.

1.2 Language as communicative action

1.2.1 Speech acts

The idea that language is used to perform actions in a communicative setting, was also elaborated by Austin (1962) and Searle (1969, 1979) in their Theory of Speech Acts. Similar to Wittgenstein, they rejected the idea that the sole function of language is a descriptive one and instead argued that language is used to carry out linguistic actions, that is, *speech acts.* For instance, the utterance *"Give me a pen"* clearly does not have the function of attempting to describe the world but is rather used to perform the linguistic action of a *request.*

An important insight from Speech Act Theory is that speech acts can be typically decomposed into three different acts (Austin, 1962; Searle, 1969). When producing an utterance, the speaker carries out a *locutionary act*, that is, they produce an utterance that is well formed and meaningful according to the rules of grammar, including a *propositional act*, namely, they are expressing a proposition, with a specific meaning. By carrying out the locutionary act, the speaker is also carrying out an *illocutionary act*, that is, they are speaking with a specific communicative intention (e.g., that of *requesting*, *thanking*, *promising*, *threatening*, etc). Finally, by carrying out the illocutionary act, the speaker carries out a *perlocutionary act*[1], in that they might cause a certain perlocutionary effect on the listener, such as persuading, amusing, frightening, etc. For instance, the effect of a *request* is that the requested action is carried out by the listener[2].

Importantly, these acts are not parallel to one another, but rather embedded into one another (see Figure 1.1), so that a specific illocutionary act is carried out *by* producing a certain locutionary act and a certain perlocutionary effect may be achieved *by* carrying out a certain illocutionary act. This distinction between locutionary and illocutionary acts is reflects the fact that the communicative function is relatively independent of the linguistic form used to carry it out. This is well

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[1] The characterization of the perlocutionary act as a *speaker's act* has met some criticism. For instance, Gu (1993) argued that in many cases, the perlocutionary act is in fact about an action of the hearer, not of the speaker. However, Kissine, 2013a argues that perlocutionary effects can nevertheless be considered as an act of the speaker because they are an effect achieved *by the means* of the production of a certain utterance by the speaker.

[2] Some scholars make a distinction between perlocutionary effects intended by the speaker from unintended ones (e.g., Kissine (2013a)), and others indeed restrict the perlocutionary act to only the latter (e.g., Bach and Harnish, 1979).

exemplified by the fact that a minimal linguistic form such as the word "water" can be used to either *name*, *request*, or *warn* depending on the context in which it is uttered. In the present dissertation, the illocutionary act is of central interest.

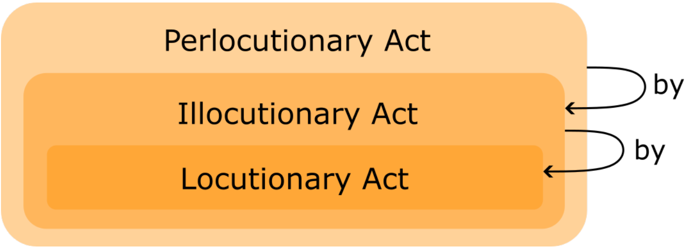

Figure 1.1: Schematic visualization of the structure of a speech act, as proposed by Austin (1962) and Searle (1969).

In addition, when we communicate, we use language for a large variety of communicative functions, that is, speech act types or illocutionary forces. Different categories of speech act types can be distinguished on the basis of similarities between their illocutionary forces. A classic taxonomy (see Kissine (2013b) for a discussion of available taxonomies) was offered by Searle (1979), who proposed that speech acts can be grouped into five distinct classes, mostly based on the differences in the purpose of the acts. The first category of *Assertives* groups the speech acts that commit the speaker to the propositional content being the case and whose propositional content is assessable on the dimension of truth. To this class belong speech acts such as *state*, *describe*, *inform*, etc. The class of *Directives* has as its commonality the fact that they are used to get the listener to do something. Examples are *ordering*, *requesting*, *suggesting*, etc. Speech acts from the class of *Expressives* express the speaker's psychological state, such as in the case of *thanking*, *condoling*, *apologizing*, etc. The class of *Commissives* groups speech acts whose purpose is to commit the speaker to a future course of action, such as in the case of *promises*, *offers*, or *threats*. The last class is that of *Declaratives*, whose very performance changes the state of affairs. Typical examples of such speech acts are highly institutionalized and therefore strongly depend on the specific formulations, procedures, and institutional roles of the speakers in order to be felicitous. Examples thereof are *baptizing*, *declaring* war, *judging* someone guilty, etc.

Speech acts can be performed successfully or unsuccessfully (see notions of *defectiveness* by Searle, 1969, or *infelicity* by Austin, 1962). Whether a speech act is performed successfully depends on whether certain conditions are met. For instance, the act of a speaker (S) *inviting* a hearer (H) for a dinner out requires that the following assumptions are met: (i) the proposition expressed by S contains the event of a dinner out in the (near) future; (ii) it is not obvious that H would take part in the dinner on their own initiative; (iii) S is in the position of inviting other people for dinner; (iv) S believes that H might be capable of joining (v) S believes that H might have an interest in joining; (vi) S wants H to join; and, finally (vii) the utterance produced by S counts as an undertaking to get H to commit to joining the dinner activity. These conditions, interestingly, differ for each illocutionary force. Importantly, when the speaker performs a certain speech act, they commit to the belief that these conditions are met and can be held accountable if they are not (Alston, 1964). As more commitments are undertaken during a conversation, these add up and are kept track of by the conversational partner(s), so that potential contradictions or inconsistencies in the conversation can be detected (Hamblin, 1970). In addition, the belief that these conditions obtain is not a mere "private belief" of each conversational partner, but instead becomes a shared belief and part of the common ground between them, namely the mutually shared knowledge between them (Clark, 1996; Stalnaker, 2002; Stalnaker, 1978).

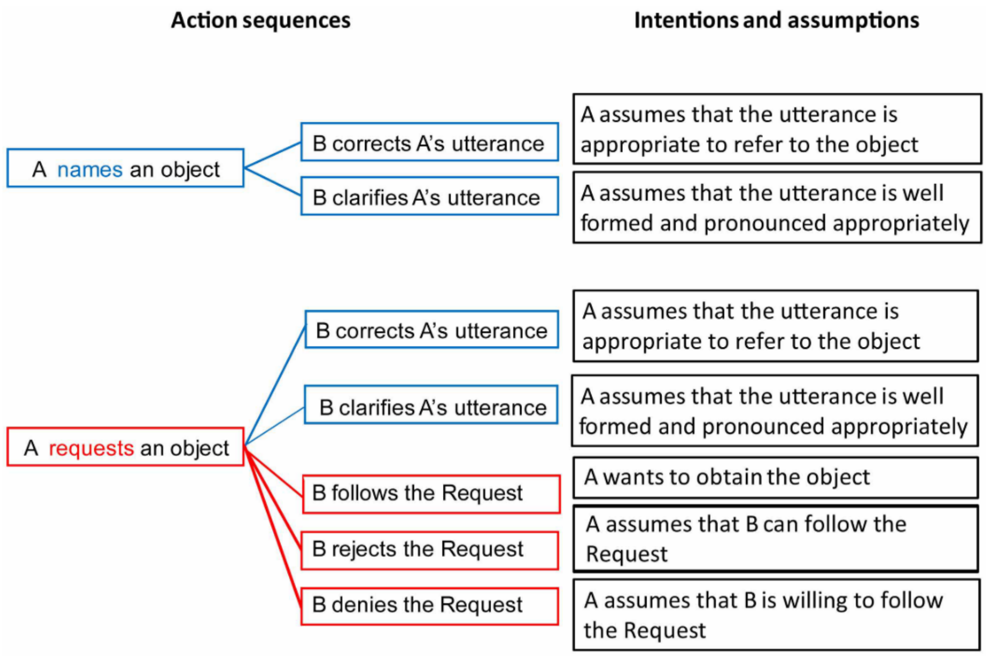

Figure 1.2: Comparison of the action sequence trees of the exemplary speech acts of *naming* (in blue) and *request* (in red) including their related assumptions and commitments (in black). Figure taken from Egorova et al. (2013) and originally published under a CC-BY license.

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As the prototypical case of communication is dialogue (Clark, 1996; Levinson, 1983; Pickering & Garrod, 2004), speech acts typically occur in close succession while conversational partners interact. Importantly, the sequence of speech acts within or across turns in conversation is the object of constraints. Each speech act might be the object of constraints projected by the previous linguistic action and also itself projects some constraints on the next linguistic action. There is a link between the constraints that one turn projects to the next and the commitments to assumptions associated with a given speech act. That is, if the speaker, by carrying out a given speech act, has committed to its associated assumptions, these assumptions will both open up and preclude possibilities for the next moves in conversation (Fritz, 2013). For instance, the speech act of person A *accusing* person B is likely to open up a range of responses for B, such as (a) *denying* the accusation, (b) *admitting guilt*, or perhaps (c) *presenting some excuses* to A. If B *denies* the accusation, it is likely that they will subsequently justify their behavior, which might again be followed by A arguing against the justification, etc. Conversely, if A has *accused* B, therefore committing to the belief that B is guilty of some crime, then this will preclude A's possibility of later *stating* that B is innocent without incurring some sanction or repair sequence in conversation. Similarly, if A *requests* an object from B (see Figure 1.2), A commits to a series of assumptions being met, such as (i) wanting the *requested* object, (ii) assuming that B can follow the *request*, (iii) assuming that B wants to follow the *request*, etc. Subsequently, B might be cooperative and hand in the requested object, but might also counter assumption (ii) by *rejecting* the *request* or assumption (iii) by *denying* the request, and so on. However, after producing the *request*, A cannot *state* that they do not want B to hand in the object, because this would generate an inconsistency with the assumption (i). Each speech act, therefore, defines what the next possible speech acts are in conversation. A speech act is therefore embedded in an *action sequence tree* (Fritz and Muckenhaupt, 1981a, 1981b; Fritz, 1994, see also *adjacency pairs* in Schegloff and Sacks, 1973). Therefore, if a speech act can be seen as the unit of communication (Searle, 1969), these units are often linked to one another in dialogue to constitute prototypical, partially predictable sequences.

To sum up, in this section, I have characterized the notion of speech acts (i.e. communicative actions or illocutionary acts) at the linguistic level and have thereby touched upon many of their central aspects. In particular, I have highlighted how the illocutionary force can be examined separately from the utterance used to carry it out. In addition, I have summarized how different types of speech acts are associated with different assumptions to which the speaker commits and that enter the common ground between conversational partners. In turn, the assumptions associated with a given speech act type define the action sequence trees into which the speech act is embedded. These considerations of a theoretical nature are crucial for formulating informed hypotheses about the neurocognitive systems involved in speech act processing.

1.2.2 Indirect speech acts

When interacting by means of language, there are cases in which the speaker *"utters a sentence, means what he says, but also means something more"*, namely *"means another illocution with a different propositional content."* (Searle, 1979). In other words, the speaker *means* something that goes beyond what is being *said*, that is, beyond the conventional meaning of that utterance. Therefore, the speaker can be said to implicate (+>) additional messages (Grice, 1975). Such phenomena have been called *indirect speech acts*.

Example (1)
Person A: "Shall we go to the movies tonight?"
Person B: "I have to study for an exam."
+> B cannot come to the movies that night.

Example (2):
Person A: "Is your cat hurt?"
Person B: "I am bringing it to the vet."
+> B's cat is hurt.

Although indirect speech acts have been the object of much attention in linguistics, different definitions have been provided (see Ruytenbeek, 2021, for a review). These definitions include considerations of the relation between the direct and indirect illocutionary forces carried out by the means of a given utterance. For instance, a classic definition is given by Bach and Harnish (1979) and Searle (1979), for whom the central characteristic of an indirect speech act is that the speaker carries out one (primary) illocutionary act *by* means of another (secondary) illocutionary act. In our first example, the speaker *declined* an invitation by *stating* that they had to study for an exam. In the second example, the speaker *asserts* that the cat is hurt by *asserting* that they are bringing it to the vet. The same utterance is therefore used to carry out two different speech act types, which also come with their own different propositional content (Bach and Harnish, 1979; Searle, 1979, see also Kissine, 2013a). Note that indirect speech acts can also take conventionalized forms (also called *standardized* indirect speech acts by Bach and Harnish, 1979; Ruytenbeek, 2021 or *primary* indirect speech acts Kissine, 2013a). Examples thereof are constructions such as "Can you [VP]?" (e.g., "Can you wash the dishes?"), which, despite their possible direct interpretation as an ability *question*, are conventionally used and understood as *requests* to perform the action. These conventionalized speech acts are, however, not the object of the present work.

If the meaning of non-conventionalized indirect speech acts is not part of their conventional meaning, how can they be understood by the addressee? Several factors, such as relying on a theory of speech acts, on information that is part of the common ground between the speaker and the hearer (including previous conversational commitments), on a general ability to make inferences, as well as on general principles of cooperation in conversation, are likely to play a role (Searle, 1979). For instance, Grice (1975) proposed that conversation is a cooperative enterprise between conversational partners. In addition, he proposed that conversation is constrained by a set of conversational principles that are typically tacitly accepted. These principles are observed by speakers and assumed by the listener during comprehension:

Cooperative Principle (CP)
Make your conversational contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which you are engaged.

Maxim of Quantity
1. Make your contribution as informative as is required (for the current purposes of the exchange).
2. Do not make your contribution more informative than is required

Maxim of Quality
Try to make your contribution one that is true:
1. Do not say what you believe to be false.
2. Do not say that for which you lack adequate evidence.

Maxim of Relation
Be relevant.

Maxim of Manner
Be perspicuous:
1. Avoid obscurity of expression.
2. Avoid ambiguity.
3. Be brief (avoid unnecessary prolixity).
4. Be orderly.

Interestingly, according to Grice, when such maxims appear to be intentionally violated ("flouted") in conversation, typically, a *conversational implicature* is produced: the addressee still assumes that the conversational endeavor is cooperative and searches for further meaning in the utterance. In this framework of Gricean conversational implicature, indirect speech acts are those that appear to violate specifically the maxim of relevance (hence relevance implicature), because their content does not appear to be an immediately relevant response to the offer based on its conventional sense. Therefore, there is a great substantial overlap between the notion of indirect speech acts and that of relevance implicature, and the two concepts have often been treated as the same (see e.g., Ruytenbeek, 2021). Grice's original maxims have inspired alternative neo-Gricean accounts consisting of adding novel maxims (Bach & Harnish, 1979; Leech, 1983), or of simplifying the original account by reducing the number of maxims (see e.g., the accounts by Horn, 1984; Horn and Ward, 2005 and Levinson, 1983, 2000) sometimes to the point of reducing them to the single principle of Relevance, as postulated in Relevance Theory (Sperber & Wilson, 1996). Despite the variability in conversational maxims and principles proposed in the literature, a notion of Relevance is maintained in all accounts.[3]

Therefore, when hearing the reply "I have to study for an exam." from example (1), the addressee deploys a chain of reasoning integrating the knowledge that an invitation can be typically accepted or rejected (theory of speech acts), that it is known to both conversational partners that studying for an exam is a time-consuming and demanding activity (common ground), which might not be compatible with going to the cinema (ability to make inferences) and that conversation follows certain cooperative principles (e.g., the relevance maxim). The addressee can eventually infer that what the speaker really meant was to decline the invitation. Although such inference can be spelled out in a detailed chain of smaller inferential steps (about 10 for Bach and Harnish, 1979; Searle, 1979), the psychological plausibility of such explicit reasoning is questionable. Indeed, both these authors emphasize how *"in a normal conversation, of course, no one would consciously go through the steps involved in this reasoning"* (Searle, 1979) or that *"detailed as it is, the SAS* (Speech Act Scheme, note of the author) *does not represent the precise form of inference (to be) made by the hearer"* (Bach & Harnish, 1979). Therefore, it is still an open question how such an inference is actually implemented in the minds and brains of the hearer.

Indirect speech acts (i.e., relevance implicatures), similar to other types of conversational implicatures, have specific characteristics (Grice, 1975; Levinson, 1983). First, they are *context-dependent* (from both linguistic and non-linguistic contexts) and, as such, they are considered *particularized* conversational implicatures, as opposed to the *generalized* ones, which are context-independent. For instance, our example "I have to study for an exam." implicates the *declination* of an offer only

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[3] Including the Levinsonian one, in which it appears to be incorporated into his I-principle.

when produced in the dialogic context of an *offer*. It would be difficult to draw the same inference if the utterance were produced in a different context. Second, an implicated proposition is not *entailed* by the proposition expressed literally by the utterance. For instance what the speaker really means when they utter "I have to study for an exam." is something along the lines of "I cannot go to the movies with you because I have to study for an exam". This proposition is, however, not entailed by the utterance but simply implicated by the speaker and probabilistically inferred by the listener. Third, what is implicated is typically *cancellable*, meaning that the speaker might indicate in subsequent utterances that no implicature was intended (Grice, 1975; Levinson, 1983). For instance, after saying "I have to study for an exam.", person B might add "...but I think I can find some time around 7pm", thereby cancelling the indirect *declination* of the invitation. Fourth, implicatures are often characterized by a certain *indeterminacy*, meaning that it is not always easy to exactly determine *what* is being implicated, because many implicatures could be compatible with the situation. Fifth, relevance implicatures are also *calculable*, meaning that it should be possible to spell out the logical process of inferences necessary to compute the implicature itself. Finally, relevance implicatures (at least the non-conventionalized ones that are the object of this dissertation) are typically *non-detachable*, meaning that the implicature depends on the conventional meaning of the utterance rather than on its exact form, and it is usually not possible to "get rid of it" by formulating the utterance differently.

To sum up, in this section I have characterized the second linguistic phenomenon of interest, that is, indirect speech acts. Similar to the previous section on speech acts, the linguistic properties of indirect speech acts that I have summarized here, particularly the link to the relevance maxim, the indeterminacy, the cancellability, and the lack of entailment of implicated contents by the utterance's conventional meaning will be crucial to guide neurocognitive investigations of this phenomenon.

1.3 Neuropragmatics

1.3.1 Why looking at the brain?

In spite of disagreements about its delimitation from other cognitive functions, it is an established view that language is a mental phenomenon and has a cognitive nature (Croft & Cruse, 2004; Jackendoff, 2002; Langacker, 1986; Noam Chomsky, 1986; Tomasello, 2003). As a consequence, to understand the cognitive underpinnings of language, a psycholinguistic approach has been taken, borrowing the typical methodology of cognitive science: making inferences about cognitive processes by observing their behavioral output. Therefore, psycholinguistics typically relies on direct measures of linguistic behavior such as accuracy, reaction times, or eye-tracking measures as access points to cognitive process(es) of interest. This psycholinguistic approach has allowed several proposals on the cognitive processes underlying both speech production and comprehension (e.g., Abdel Rahman and Melinger, 2019; Levelt et al., 1999; Marslen-Wilson, 1987; Pickering and Garrod, 2013) and has also allowed studying the processing of pragmatic aspects of language more specifically (Sauerland & Schumacher, 2016).

However, cognitive processes are the product of patterns of neural activations and rely on a neural infrastructure, so that damage to this infrastructure or alteration in its activity patterns results in cognitive deficits, including language-related ones (e.g., Lichtheim, 1885; Wernicke, 1989). Therefore, a neuroscientific approach consisting of observing and, where possible, manipulating brain activity can also be a useful additional entry point to the study of cognitive functions (Henson, 2005), including language function. Indeed, observing different patterns of brain activations under two different experimental conditions is evidence for differences in cognitive processes between these conditions. For instance, detecting different patterns of brain activations when processing two types of linguistic stimuli indicates that different cognitive processes might be at work, even in the absence of differences in behavioral measures. Similarly, finding similar patterns of activation between different tasks might indicate that similar cognitive processes are involved (Henson, 2005; Poldrack, 2006). From a theoretical point of view, given that behavior, including linguistic behavior, relies on brain structure and function, it is also subject to related structural and functional constraints. Because neuroscience might provide reasons for *why* a certain cognitive process takes place in a certain way rather than in another (Pulvermüller, 1999; Ward, 2010), cognitive models of linguistic behavior might benefit from being informed by cognitive neuroscience in the quest for neurally plausible cognitive models. From a methodological point of view, taking a neuroscientific approach offers the unique chance to go beyond the observation of the final *output* of a cognitive process (overt behavior). Instead, it allows one to directly observe neural indicators of the cognitive process unfolding over time. In addition, measuring brain activity can also help avoid, if needed, resorting to behavioral tasks altogether. This can be useful under certain circumstances, for instance, in cases in which having an active task might confound the linguistic process of interest or in cases in which the human population under scrutiny is not easily amenable to performing a task (e.g., infants, children, clinical populations). Finally, examining the neuronal correlates of language function is important for its applications, particularly in a clinical perspective, to better understand, diagnose, and treat language disorders such as aphasia (Berthier & Pulvermüller, 2011; Pulvermüller & Berthier, 2008), developmental dyslexia (Goswami, 2011; Peterson & Pennington, 2012), and many others. Narrowing our focus to pragmatics, pragmatic function has been shown to be impaired in some clinical populations (e.g., schizophrenia; see Bambini et al., 2016). In addition, some patients appear to have deficits specifically in the pragmatic domain, such as difficulties in using communication for social purposes, in comprehension of non-literal language, in following rules of conversation, etc., in the absence of other language-related deficits or other cognitive deficits. This has motivated the recent addition of the diagnosis of neurodevelopmental Social (Pragmatic) Communication Disorder to the 5th edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2013; Swineford et al., 2014). The application of a cognitive neuroscience approach for understanding the neuro-cognitive underpinnings of language function has resulted in several accounts of how linguistic function is realized by the brain (Friederici, 2011; Hagoort, 2013; Hickok, 2014; Lambon Ralph et al., 2016; Pulvermüller, 2018) including, more recently, pragmatic function (Hagoort & Levinson, 2014; Noveck & Reboul, 2008).

1.3.2 Neural correlates of Speech Acts

Earlier studies in neuropragmatics focused on the neural correlates of the presence of a general communicative intention (Enrici et al., 2011; Noordzij et al., 2009; Stolk et al., 2014; Tettamanti et al., 2017; Willems et al., 2010), reporting activations in the Intention Processing Network (IPN, Bara et al., 2015; Enrici et al., 2019), a brain network showing substantial overlap with the brain network believed to support Theory of Mind (ToM) function (Schurz et al., 2014; Schurz et al., 2021; Van Overwalle & Baetens, 2009), that is the ability to understand other people's mental states such as beliefs, desires, or goals (Leslie, 1987; Premack & Woodruff, 1978). In recent years, research has attempted to examine the neural correlates of different types of communicative functions. Following the Searlean classification of speech acts (Searle, 1979), attention was focused on contrasting the Searlean assertive or directive class (see Tomasello, 2023 for a review). The approach taken was to take identical utterances (words or sentences) and vary their communicative function using dialogic (Egorova et al., 2014; Egorova et al., 2013, 2016), gestural (Tomasello et al., 2019) or prosodic cues (Tomasello et al., 2022).

For instance, in a first series of studies, the word "water" was used in different dialogic contexts to either *name* or *request* some water (Person A: (*NAMING*) "What is this?" / (*REQUEST*) "What can I get you?", Person B: "Water"). Interestingly, it was shown that neurophysiological brain responses during comprehension of naming and request speech acts differed, and they did so about 200 ms after word onset. These studies demonstrated that a rapid processing of speech act type is possible in contexts in which the speech act type can be anticipated because of the preceding dialogic context (Egorova et al., 2014; Egorova et al., 2013). Indeed, further work by Gisladottir et al. (2015) also demonstrated that neural signatures related to speech act type could be identified even before the presentation of the critical utterance, if the previous dialogic turn was predictive of the speech act type of the incoming critical turn. Further studies, examined neural processing of the same speech acts in experimental designs where the cue about the type of speech act was not given before the critical utterance, but rather simultaneously, preventing anticipated identification of speech act type. For instance, in a study by Tomasello et al. (2019) the very same two speech acts were realized by combining the same single words with either a pointing gesture in the case of a *naming* speech act or an open hand gesture in the case of a *request.* Even under these conditions, neurophysiological responses to *naming* and *requesting* actions differed very early from one another (around 150 ms from critical stimulus onset). Finally, Tomasello et al. (2022) examined another pair of speech acts: *statements* (assertives) vs. *questions*, which so far have had a controversial position in a taxonomy of speech acts. They compared identical sentences marked by different pitch contours to indicate whether the utterance was to be taken as a *statement* (final falling pitch) or as a *question* (final rising pitch). Once again, it was found that dissociations between the two kinds of speech acts occurred early on, 100 ms after the onset of the critical spoken word. Therefore, examination of the neurophysiological correlates of speech act processing has provided evidence that speech act information is processed rapidly independently of the form of the utterance (e.g., words or sentences) or the cue used to mark it (preceding dialogue, prosody, gestures) and in contexts in which the speech act type cannot be anticipated.

Besides providing information about the time course of processes engaged during speech act type comprehension, brain data can also provide information about which cognitive systems are likely to be involved in speech act type processing. Interestingly, contrasting *naming* and *request* speech acts revealed strikingly consistent spatial patterns of activation across experiments. In an fMRI experiment, (Egorova et al., 2016), similar to the previous experiments, Egorova et al. had subjects comprehend naming and requesting actions. They found that when contrasted with *naming* speech acts, *requesting* speech acts activated (among others) regions in the motor cortex as well as in the Theory of Mind brain network (Schurz et al., 2014; Schurz et al., 2021; Van Overwalle & Baetens, 2009). Several of the EEG studies discussed above also provided information about the localization of the differences between *naming* and *request* by performing source analysis to estimate the sources generating the neural signals (Litvak et al., 2011). For instance, Tomasello et al. (2019) also found larger activations for *requests* in the hand motor region, while Tomasello et al. (2022) found activations in the articulatory motor regions for *questions*. A further source of information comes from fMRI studies investigating indirect *requests*, which highlighted how indirect *requests* activated both the motor system and the ToM system in the brain (van Ackeren et al., 2012). In a follow-up study, the comprehension of indirect *requests* relative to indirect (non-directive) replies was characterized by activations in the motor systems (bilateral IPL and left M1), indicating that these motor system activations are related to the illocutionary force of a *request*, rather than to its indirectness (van Ackeren et al., 2016). Therefore, it appears that, compared to speech acts from the assertive class, directive ones are consistently associated with stronger activations in the motor system, and potentially also the ToM system.

Overall, these results can find an explanation in the framework of the Theory of Action Prediction in Communication (TAPCo model, Pulvermüller, 2018; Pulvermüller et al., 2014), which, importantly, relies on both linguistic observations and basic principles of neural function. Starting with the former, it has already been described in Section 1.2.1 that speech act types can be characterized by their prototypical action sequence tree. The prototypical response to the speech act of a *request* is that the listener responds to it by handing in the requested object, that is, by producing a motor response (Fritz & Muckenhaupt, 1981b). Crucially, however, a motor response is not a prototypical follow-up on a *naming* speech act. Therefore, one might say that the *request* speech act, but not the *naming* one, is associated with an expectation that a physical action is going to be performed by the communicating partner. Interestingly, neuroscientific studies, have demonstrated the existence of neuronal systems that respond equally to action performance and to the observation of the same action being performed by someone else (Bonini et al., 2022; Rizzolatti & Craighero, 2004). Further work has also demonstrated that the motor activations in the brain of an observer can be detected also prior to the observation of an anticipated action (Bozzacchi et al., 2014; Kilner et al., 2007; Kilner et al., 2004). These two lines of evidence combined suggest that the motor cortex activations detected during the comprehension of *requests* might be explained by the anticipation of the motor response of the addressee. Motor activation detected during comprehension of *requests* might therefore be inherent to the neural representation of a request (or other directives). The integration of this motor activity in the representation of *requests* might be the result of repeated exposures to sequences of producing utterances to carry out *requests* and subsequent handing in of the object during language acquisition. This contingency between activation in the perisylvian language cortex related to the production and/or perception of an utterance and the activation in the motor cortex related to the production of one's own response or the observation of other's response might become associated at the neural level by the principles of Hebbian learning (Hebb, 1949; Pulvermüller, 1999). As a result, the neural representation of a *request* might emerge with time in the form of functionally linked cohorts of neurons (cell assemblies) distributed in the perisylvian language cortex and in the motor cortex. The TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014), therefore, provides a framework to explain the detected patterns of neuronal activations found for *request* vs. *naming* speech acts. Importantly, the model also provides a theoretical framework that generates new hypotheses concerning the neural processing of the underinvestigated speech act types.

If neurolinguistic examination has provided some insights into the spatiotemporal dynamics of speech act type processing, several questions remain unanswered. In particular, previous research exclusively examined the processes of speech act in the comprehension modality, while speech act production remained essentially unaddressed. It is therefore unclear whether the neural signatures found in one modality will extend to the other. Note that different models of language processing might make different predictions in this respect: some might predict the same and some different representations in comprehension and production modality (see Section 1.3.4). Another consideration is that all studies mentioned so far examined speech act processing outside of any real social and interactive setting. This is particularly problematic for the investigation of a pragmatic phenomenon, which by definition is the use of language in context, including social context. From this point of view, it is also not clear whether the above-mentioned findings generalize to more realistic social-interactive settings, that mimic naturalistic situations in a more ecologically valid manner.

1.3.3 Neural correlates of Indirect Speech Acts

Neurocognitive research has also been used to tackle the question of how (non-conventionalized) indirect speech acts are processed. Indeed, the challenge of such a phenomenon resides in the fact that the speaker carries out a speech act by means of another speech act (Bach & Harnish, 1979; Searle, 1979). The indirect message, therefore, needs to be inferred by the hearer. The exact nature of this process has remained elusive. Earlier behavioral experiments have demonstrated that responding to an utterance used to carry out an indirect speech act results in higher processing costs than when the same utterance is used to carry out a direct speech act. This finding is robust across a variety of measures such as comprehension time (Holtgraves, 1999, Experiment 6), reading times (Hamblin & Gibbs, 2003), latency of judgment about the interpretation of an in/direct reply as meaning “yes” or “no” (Feng et al., 2017; Feng et al., 2021; Jang et al., 2013) or as conveying a message with a positive, neutral, or negative valence (Shibata et al., 2011). In addition, these studies covered a variety of languages (English, Korean, Japanese and Chinese), speaking for the cross-linguistic robustness of these effects. Together, these behavioral measures indicate that processing indirect speech acts is more challenging than processing direct ones. This finding is consistent with the theoretical consideration that they might involve a form of inference (Grice, 1975; Searle, 1979, see also Section 1.2.2). However, they have so far not provided much information about what specific kind of inference or processing might be involved.

In the last decade, several brain imaging studies - particularly fMRI studies - have been employed to assess which brain networks are active during comprehension of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011). Similar to the study of speech acts, a strategy that has often been used in this domain is to have the same exact critical utterance preceded by different context sentences, which bias the reading of the critical utterance towards a direct or indirect interpretation. For instance, the reply "It's hard to give a good presentation" is a direct reply to the question "How is it to prepare a presentation?" in the context of two people discussing workload related to going to conferences. However, the very same reply was used in response to the question "Will you choose a presentation?" while students are deciding which examination format they want to choose for their course evaluation, is used indirectly, to say that the speaker will choose something other than a presentation (examples taken from Bašnáková et al., 2014). Both earlier studies that did not match the sentence in the direct and indirect conditions (Jang et al., 2013; Shibata et al., 2011) and later studies that did capitalize on this approach (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021) provided converging evidence that comprehension of indirect speech acts engaged a set of regions equally distributed over both brain hemispheres (see Figure 1.3 and Table 1.1 for a summary). In particular, brain regions typically involved in language processing, such as the inferior frontal gyrus (IFG) and middle temporal gyrus (MTG), including their right-hemisphere homologues, are found with high consistency across studies (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011). These activations are often interpreted as relating to processes such as "semantic unification" or "integration" (Bašnáková et al., 2014), "context integration" (Bašnáková et al., 2015), or "coherence building" (Feng et al., 2017; Jang et al., 2013). They are based on the consideration that indirect speech acts, because of their known context-dependence, might require additional effort to be semantically integrated during conversation, and additional effort might be required to build a coherent situation model. In addition, in the literature, processing of indirect vs. direct speech acts is found to be associated with activations in the middle prefrontal cortex (mPFC) with high consistency as well as in the precuneus (preCun) and the bilateral temporo-parietal junction (TPJ) with moderate consistency (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2012; van Ackeren et al., 2016). This network largely overlaps with the brain network supporting Theory of Mind (ToM) function (Schurz et al., 2014; Schurz et al., 2021; Van Overwalle & Baetens, 2009). Indeed, indirect speech acts might be associated with a greater ToM load related to the effort of attempting to understand the other's intentions in communication, which is not explicitly conveyed. This engagement of the ToM network for comprehension of indirect speech acts is also convergent with an already mentioned different line of work that found that *requests* carried out indirectly activated both motor (SMA, IPL) and ToM regions, including the TPJ and the mPFC (van Ackeren et al., 2012) and determined that activities in the motor system could be related to the fact that the utterances were used to carry out *requests*, while activity in the ToM network could be related to the fact that the utterances were indirect (van Ackeren et al., 2016).

Therefore, overall, neuroimaging investigations of indirect speech act comprehensions have so far shown consistent activation of language areas (bilaterally) and moderately consistent activation of the ToM brain network (see Table 1.1 and Figure 1.3). However, the conclusions drawn from these studies can be subject to criticism from three distinct points of view. First, neuroimaging results typically "only" allow determining which brain regions are active during a given task, e.g., comprehension of indirect vs. direct speech acts. Usually, the step from brain networks to cognitive processes is done on the basis of so-called reverse inference (Poldrack, 2006). The basic reasoning behind this approach is that if networks that are known from other studies to be responsible for a given cognitive function are also active during comprehension of indirectness, these cognitive processes must be at work during comprehension of indirectness. Although this interpretative strategy is commonly used in neuroimaging, it comes with limitations because it only indirectly suggests the involvement of a given cognitive process. Second, an inherent limitation of neuroimaging, is that it provides only correlational evidence for the involvement of a certain brain region in a certain task. In other words, a certain task might be associated with activations in several brain regions that are only epiphenomenal, i.e., that do not causally participate in the cognitive process of interest. For instance, an indirect speech act comprehension task might in principle not only activate the cognitive mechanisms (and related neural networks) for processing indirectness, but it might also incidentally activate other systems (e.g., the affective system, if the indirect speech act was a veiled negative opinion) that are not part of the indirectness comprehension mechanism but might instead correspond to some additional post-processing of the indirect speech act. Third, the kind of indirect speech acts investigated so far did not allow a clean inspection of the phenomenon of indirectness, because the categories of the speech acts (as in Searle, 1979) in the direct and indirect conditions were not systematically matched. It is therefore possible that comparing direct and indirect speech acts might have also captured neural differences related to the difference in speech act category. Note that there is some preliminary evidence that neural signatures of a specific type of illocutionary force (*request*) are present even when that speech act is performed indirectly (van Ackeren et al., 2012; van Ackeren et al., 2016). In other words, the illocutionary forces (both direct and indirect) expressed by indirect speech acts can act as a confounding factor and can constitute an obstacle to the identification of neurocognitive mechanisms of indirectness. Therefore, additional studies are required to support (or not) conclusions based on reverse inference and to identify which brain regions are *causally* involved in the comprehension of indirectness itself and which regions might instead be processing other aspects of the utterance, such as its illocutionary force.

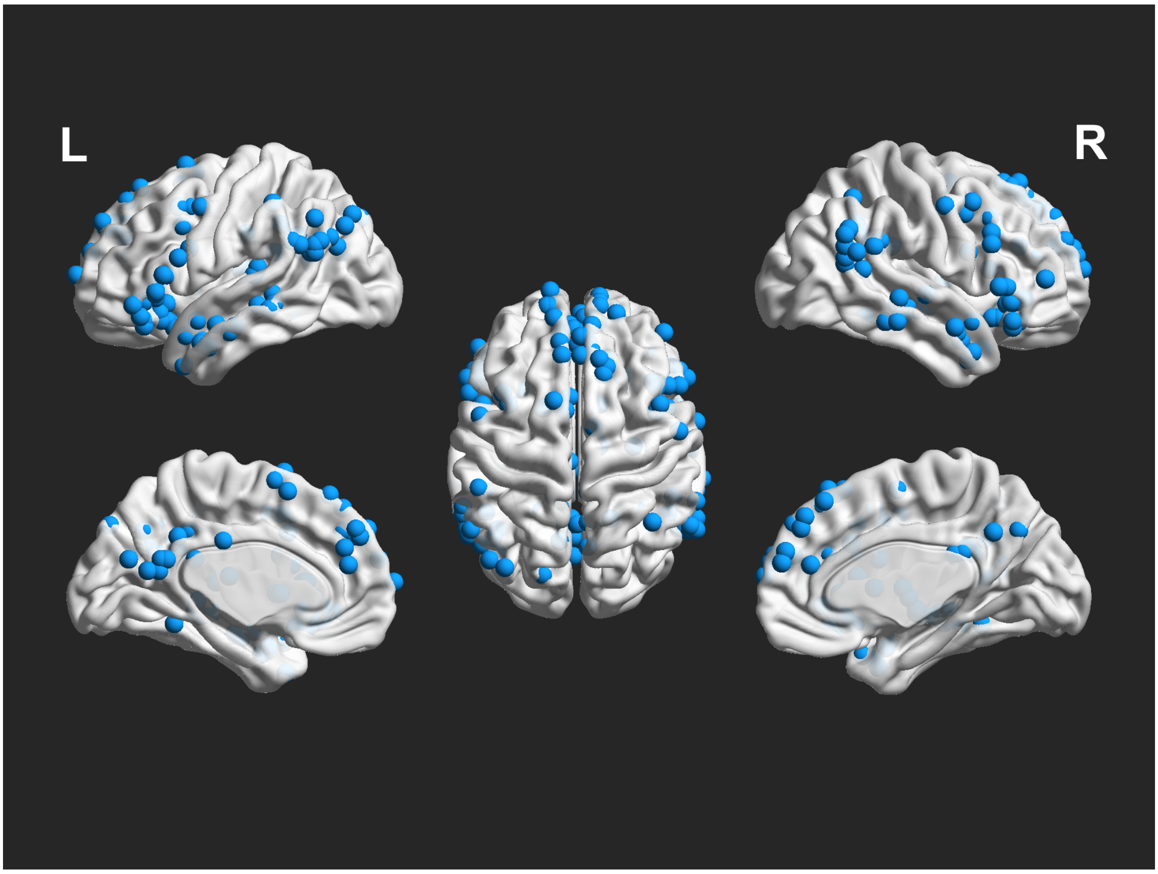

Figure 1.3: Peak activations found in the literature summarized in Table 1.1 for indirect speech acts (vs. direct ones). Each peak is located on an MNI template brain by means of spheres with a 5 mm radius. The figure was produced with BrainNet Viewer (Xia et al., 2013).

Publication	**medial**								**frontal**						**temporal**						**temporo-parietal**				**fronto-parietal**						**Other**
	preCun		**pcc**		**acc**		**mPFC**		**SFG**		**MFG**		**IFG**		**TP**		**MTG**		**STG**		**ANG**		**SMG**		**M1**		**PMC**		**SMA**		
	L	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	
Shibata et al., 2011 *indirect reply > literal sentence*	23/31							8/9			9		47	9/47				21													
Jang et al., 2013 *highly implicit > explicit*	19		30				10/9		9/10				47tri		38		21	21	38/ 39		39										L fusiforn gyrus
Jang et al., 2013 *parametric (by implicitness ratings)*	19		23	31			10		6/9/ 10	9		46	45tri/ 47tri	44	38	38	21	21	39		39		40	40		4					L putamen, R fusiform gyrus, L parahipp. gyrus
Bašnáková et al. 2014 *pooled indirect replies > direct replies*							32	8					47	47/49				21				39/40								8	L anterior insula
Bašnáková et al. 2016 *pooled indirect replies > direct replies*							x	x				x	tri/ orb	tri/op	x	x	x	x	x	x	x	x				x			x	x	R thalamus, R insula, R pallidum
Van Ackeren et al., 2012 *IR > (PC, UC, PUC)*	x	x	x	x	x	x		x					orb	tri/op				x		x	x	x	x	x	x						R insula, L insula, R putamen, bilateral thalamus
Van Ackeren et al., 2016 *indirect speech > direct speech*								x					x																x		bilateral caudate
Feng et al., 2017 *pooled indirect replies > direct replies*	17/23	17/23											45/47	45		38	20/21	20/21			39	37/39									
Feng et al., 2017 *parametric (by indirectness ratings)*	23	23					10	10			9			47	20/38	20/21 /38	20/21	20/21			39	39									
Feng et al., 2021 *PI > PIC*	23		23				9/10	8					45/47	45/47			20/21	20/21			21/39	22/39					6	6			
Bendz et al., 2022 *indirect (both groups) > direct (both groups)*	x	x					x	x					x	x		x	x	x			x	x									L cerebellum
Number of publications showing the area significantly active (out of 9)	6	3	3	2	1	1	6	8	1	1	2	2	9	8	3	4	5	8	2	2	6	6	2	2	1	2	1	1	2	2	

Table 1.1: Comprehensive summary of the peak activations found in the literature for processing of indirect (vs. direct) speech acts. Study reference and the exact fMRI contrast performed are indicated in the left column. Brain areas in which peak activations were found are marked either with a cross or, where available, with the Brodmann area number. The lower part of the table indicates numerically and visually (black bars) how many studies (out of a total of 9), found any given area to be significantly active. Note that two studies (Feng et al., 2017; Jang et al., 2013) performed both a classic contrast analysis and a parametric analysis. In such cases, an area was counted as active in a given study if it was significant in one or both of the two types of analysis. Abbreviations: L = left; R = right; preCun = precuneus; pcc = posterior cingulate cortex; acc = anterior cingulate cortex; mPFC = medial prefrontal cortex; SFG = superior frontal gyrus; MTG = middle temporal gyrus; IFG = inferior frontal gyrus; TP = temporal pole; MTG = middle temporal gyrus; STG = superior temporal gyrus; ANG = angular gyrus; SMG = supramarginal gyrus; M1 = primary motor cortex; PMC = premotor cortex; SMA = supplementary motor area.

1.3.4 Neurobiology of Language

Examining how pragmatic processes are implemented in the brain can, in addition, provide some answers to some long-standing questions in the neurobiology of language and thereby inform present models thereof.

A place for pragmatics?

When examining pragmatic phenomena such as speech acts and indirect speech acts, it is clear that these occur in concert with processes related to other aspects of the linguistic stimulus, such as syntactic, semantic, or phonological ones. A neurocognitive account of pragmatic processing, therefore, needs contextualization and integration into the broader picture of language processing.

However, the majority of contemporary neurobiological models of language that aim to explain the various aspects of language processing largely fail to account for pragmatic processing. In other words, the classic structuralist view that was dominant in linguistics strongly shaped neurolinguistic approaches, resulting in a clear focus on compositional (at various levels) and semantic aspects of language but typically leaving out aspects of language *use.* For instance, the Dual Stream Model (Hickok, 2012; Hickok & Poeppel, 2007) examines the distribution of various aspects of language processing from phonological, to lexical, to semantic or articulatory aspects across the brain in both production and comprehension modalities, but pragmatic processes are not addressed. Other influential models of language processing (Friederici, 2002; Friederici, 2011; Pickering & Garrod, 2004) might possibly allow for some kind of pragmatic processing (see the “message” in Pickering and Garrod, 2004, or the “interpretation” in Friederici, 2011). Similarly, the model by Indefrey (2011) and Indefrey and Levelt (2004) proposes sequential processing of the various aspects of linguistic processing, from conceptual preparation to actual articulation. Pragmatics is vaguely incorporated into the conceptual processing, which includes perspective taking, but the exact processes or neural substrates are not spelled out. Therefore, overall, in spite of appearing possibly open to the existence of pragmatic processes, these latter models lack specificity and therefore do not allow to generate testable predictions about which neurocognitive systems contribute to pragmatic processing.

In contrast, others have proposed models that make room for pragmatic processing and attempt to account for the dissociation seen at the neural level when contrasting different pragmatic conditions. For instance, the *Memory, Unification, and Control (MUC)* neurobiological account of language (Hagoort, 2013, 2014, 2019) proposes that, next to a “Memory” component storing linguistic units of different types (from phonemes, morphemes, words, and syntactic templates) and a “Unification" component combining them, a third component - "Control" - encompasses a range of non-language-specific processes that are flexibly recruited together with the two others, depending on the specific task requirements. This also includes the ToM brain system, which might be recruited when pragmatic aspects of language become relevant, for example, for understanding speaker meaning (Grice, 1957). Another model integrating pragmatic processing with other more classic linguistic processes is the already mentioned TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014, see Section 1.3.1). In particular, the TAPCo account is based on the consideration that speech acts are embedded in sequences of actions and that they are associated with specific intentions and assumptions (see Section 1.2.1). For instance, the speech act of requesting an object will be associated with the expectation of the next likely move in the action sequence tree, that is, that the listener is likely to hand over the requested object. Therefore, the TAPCo model predicts that *requests* might be associated with the anticipation of such motor activity by the listener and therefore manifest in the activation of motor cortices. In addition, the *request* speech act might be associated with the processing of specific assumptions or intentions, i.e., the fact that the listener is capable, willing, and/or allowed to perform the requested action. The processing of such assumptions and intentions might manifest itself, for instance, in the activation of the ToM brain system. Therefore, different speech acts might be embedded in different action sequence trees and be associated with different intentions and assumptions, therefore resulting in predictable patterns of brain activation.

Studying the neural correlates of pragmatic phenomena, including those of speech acts and indirect speech acts, should therefore contribute in the long term to positioning pragmatics in the larger picture of neurobiological models of language function.

Language as an amodal vs. grounded system?

Another debated issue is whether the language system relies solely on amodal (or multimodal) brain systems, or whether it also draws on modality-specific brain areas, such as motor or sensory areas.

The first view suggests that language is represented in a specific set of amodal brain regions, usually encompassing the IFG and different parts of the temporal lobe. According to this view, only purely "productive" (i.e., preparation and execution of articulation) and "perceptual" processes (i.e., perceiving speech sounds), are located in modal brain areas such as the articulatory motor and the auditory cortex, respectively (Friederici, 2012; Hickok, 2012; Hickok & Poeppel, 2007; Indefrey, 2011; Indefrey & Levelt, 2004). Such models postulate that the various levels of representation of linguistic stimuli are abstract and therefore independent from the neural circuits responsible for action and perception.

However, some other models postulate that language processing is grounded in action and perception and therefore relies on distributed neural networks, including primary sensorimotor cortices at all levels of language description (Pulvermüller, 2018; Strijkers & Costa, 2016). For example, at the semantic level, word meaning is represented in different sensorimotor areas corresponding to the sensory properties of the referent and to its affordances, as well as in the multi-modal areas acting as a neuronal intermediate between these sensorimotor areas (Barsalou, 1999; Binder & Desai, 2011; Binder et al., 2009; Lambon Ralph et al., 2016; Patterson et al., 2007; Pulvermüller, 2013). In addition, the phonological representation of a word is stored both in the articulatory motor cortex, which is usually activated for producing the corresponding speech sounds, and in the auditory cortex, where the corresponding sound is processed (Pulvermüller et al., 2006; Schomers et al., 2015, see Schomers and Pulvermüller, 2016 for a review). Following this logic, it has been proposed that pragmatic representations could also be grounded in the action sequence trees associated with different linguistic actions as well as with the different assumptions and intentions associated with them. Therefore, pragmatic representations could be stored at least partially in modality-specific brain areas (Pulvermüller, 2018; Pulvermüller et al., 2014).

Examining pragmatic processing can therefore inform the debate about whether language function relies solely on amodal brain areas, or whether it also draws on modal ones.

Same or different neural circuits for language comprehension and production?

Another outstanding question is whether similar neural substrates are at work during speech comprehension and speech production. The earliest neurobiological model of human language, the classic Broca–Wernicke–Lichtheim–Geschwind (BWLG) model postulated a distinction between a comprehension center situated in Wernicke's area and a production center situated in Broca's area (Geschwind, 1970; Lichtheim, 1885; Wernicke, 1989). The model, therefore, proposed a strongly modularized view of comprehension and production functions, which were considered separate processes relying on different neural substrates.

Although the BWLG model, together with its net separation between comprehension and production processes, is today considered largely outdated (Hagoort, 2014; Hagoort & Indefrey, 2014; Hickok & Poeppel, 2004; Pickering & Garrod, 2013; Poeppel, 2014; Price, 2012; Pulvermüller, 2010, 2018; Pulvermüller et al., 2009; Tremblay & Dick, 2016), the question of the degree of overlap between comprehension and production systems is still debated. Some contemporary approaches to the investigation of the neurobiology of language have focused either on one or the other, typically resulting in separate accounts for speech comprehension (e.g., Friederici, 2002; Friederici, 2012) and production (e.g., Indefrey, 2011; Indefrey and Levelt, 2004). However, other models have proposed that the very same systems or representations are used both in comprehension and production (Pickering & Garrod, 2004, 2013; Pulvermüller, 2018; Strijkers & Costa, 2016). The idea behind the latter is that a given linguistic expression activates the same brain representations both in language production and comprehension, where the representation stands for various aspects of the linguistic expression (e.g., semantic, phonological, syntactic, etc.). That production and comprehension of a linguistic expression activate the same representation however does not exclude that they might be activated with different task-dependent dynamics, e.g., with different intensities related to certain components of the representations being more foregrounded than others, or with slightly different temporal patterns (Fairs et al., 2021; Strijkers & Costa, 2016). In addition to these two groups of models, one further cluster of models of language exists in which the sharing of representations between comprehension and production concerns only the most "internal" aspects of language such as syntax and semantics, but not the "outer" aspects such as preparation of articulation or phonological processing (Hagoort, 2014; Hickok & Poeppel, 2007; Menenti et al., 2011).

Pragmatics can provide a new arena for testing whether language comprehension and production processes draw on the same representations. If measures of brain activity related to pragmatic processing in comprehension and production modalities reveal similar patterns, as proposed by some (Pickering & Garrod, 2004, 2013; Pulvermüller, 2018; Strijkers & Costa, 2016), this would be consistent with comprehension and production systems drawing on the same representations. Given that *request* speech acts were found to activate the motor system in the comprehension modality (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019) as predicted by the TAPCo model (Pulvermüller, 2018) (see Section 1.3.2), detecting similar patterns of brain motor activation in the production modality would be consistent with the view of representations of the speech act type of a *request* being shared across modalities. Conversely, if no overlap is found between activations for a given speech act in production and comprehension, this would be more consistent with the two modalities drawing on different pragmatic representations.

1.4 Focus and aim of the present work

The present work investigates the brain mechanisms that are responsible for achieving communication by means of linguistic actions. Specifically, the present work focuses on the pragmatic phenomena of speech acts and (non-conventionalized) indirect speech acts. The following questions are addressed:

- **Question 1**: Can the differences in neural signatures of *naming* and *request* speech acts previously observed in the comprehension modality be found also in speech production (also in social-interactive tasks)?
- **Question 2**: Is the right temporo-parietal junction, an important node of the ToM network, *causally* involved in the comprehension of indirect speech acts (also after controlling for speech act type)?
- **Question 3**: Do indirect speech acts systematically differ from direct ones in psycholinguistic properties, whose processing is known to be reflected in different neural processes (also after controlling for speech act type)?

These questions are addressed in three studies using a variety of methods from psycholinguistics and neurolinguistics. In line with the observation that a given linguistic form (i.e., a single word, a sentence) can be used to carry out different communicative functions, the approach taken in all three studies is to systematically manipulate speech act type and/or indirectness, while maintaining the utterance's structure constant. This allows controlling for the processes of the various aspects of the linguistic form (e.g. phonological, syntactical, lexical semantics, combinatorial semantics, etc.). Only the context will be manipulated to bias the subject toward producing or comprehending one speech act rather than another, or an indirect speech act rather than a direct one. This way, the associated cognitive and neural processes can be separated from processes related to the linguistic form, and the neurocognitive underpinnings of communication can be uncovered.

Question 1 is addressed in Chapter 2. The study will focus on two specific speech acts, *naming* (an assertive) and *requesting* (a directive), which have been previously investigated in the comprehension modality. *Requests* were so far found to be associated with comparatively higher activations in the brain motor system, consistent with the predictions of the TAPCo Model (Pulvermüller, 2018; Pulvermüller et al., 2014). Based on the TAPCo Model, and models predicting that language is based on similar representations across modalities (Fairs et al., 2021; Pickering & Garrod, 2004; Pulvermüller, 2018), we hypothesize that *requests* are associated with stronger activations of the motor system also in the production modality. Using a novel socially interactive experimental paradigm, EEG responses will be recorded prior to the production of a *naming* or *request* speech act. The analysis of the EEG signals will be focused on an event-related-potential component known as an indicator of pre-activation of the motor system: the readiness potential (RP, Kornhuber and Deecke, 1965a; Shibata et al., 2006). We therefore expect larger RPs for *requests* than for *naming*. This study will help assess whether previously uncovered representations of *request* vs. *naming* speech acts can be extended to the production modality and to more naturalistic social-interactive tasks.

Question 2 is addressed in Chapter 3. Because several studies have demonstrated how regions of the ToM brain network such as the mPFC and the bilateral TPJs are active during comprehension of indirectness, it has been suggested that ToM might be involved in the comprehension of indirectness. However, as discussed in Section 1.3.3 these studies typically did not ensure that the speech act type realized by the direct and indirect conditions were the same and might therefore have been confounded. In addition, these neuroimaging studies provide only correlational evidence for the involvement of ToM regions in the comprehension of indirectness. The hypothesis tested here is that indirect speech acts require ToM processing (unconfounded case), but that additional ToM ability might be needed for processing speech act function (speech act confounded case). To achieve this goal, transcranial magnetic stimulation (TMS) - a non-invasive brain stimulation method - will be directed to the rTPJ to alter local brain activity. Resulting alterations in comprehension of indirect (vs. direct speech acts) will be assessed in a behavioral task. Two sets of stimuli will be tested: direct and indirect speech acts matched (SA-matched) or non-matched (non-SA-matched) for communicative function. Therefore, we predict that the TMS manipulation will affect comprehension of both SA-matched and non-SA-matched indirect speech acts, but even more so in the case of non-SA-matched indirect speech acts. This study allows for assessing whether the rTPJ is *causally* involved in the comprehension of indirect speech acts while controlling for and assessing the confound of speech act type.

Question 3 is addressed in Chapter 4. Determining the cognitive properties of indirect speech acts is a useful step in identifying the cognitive mechanisms allowing their comprehension. Yet, cognitive differences between direct and indirect speech acts have not been investigated so far but have only been suggested by neuroimaging studies based on reverse inference (see Section 1.3.3). Linguistic descriptions of indirectness - in particular the fact that they result from the violation of a maxim, their cancellability, and their indeterminacy - allow for the generation of some hypotheses on their cognitive properties. In particular, here we test the hypothesis that indirect speech acts will score lower than direct ones on various cognitive dimensions: predictability, coherence with their linguistic context, semantic similarity to their linguistic context, and certainty of interpretation. In addition, we hypothesize that these dimensions will correlate with one another. These dimensions will be assessed through behavioral ratings. The same two sets of in/direct replies used in Chapter 3 that are matched or not matched for speech act type will be assessed here. Subjects will be asked to rate the following dimensions: predictability, coherence with the linguistic context, semantic similarity to the linguistic context, and certainty of the interpretation. The ratings obtained from this study will allow for qualifying and quantifying the ways in which indirect speech acts are different from direct ones, while taking the confound of speech act type into account. Obtaining this information will contribute to a better interpretation of both past and future neuroimaging studies of indirectness and support (or not) conclusions from previous studies that resorted to reverse inference (Poldrack, 2006) alone.

This series of experiments is intended to better characterize the neurocognitive processes underlying the specific phenomena of speech acts and indirect speech acts. By doing so, it will provide novel knowledge to guide the development of contemporary neurocognitive models of language processing toward explaining not only structural aspects of language but also language used for communication.

Chapter 2

Brain signatures predict communicative function of speech production in interaction

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Abstract

People normally know what they want to communicate before they start speaking. However, brain indicators of communication are typically observed only after speech act onset, and it is unclear when any anticipatory brain activity prior to speaking might first emerge, along with the communicative intentions it possibly reflects. Here, we investigated brain activity prior to the production of different speech act types. *Request* and *naming* actions performed by uttering single words embedded into language games with a partner, similar to natural communication. Starting ca. 600 msec before speech onset, an event-related potential maximal at fronto-central electrodes, which resembled the Readiness Potential, was larger when preparing *requests* compared to *naming* actions. Analysis of the cortical sources of this anticipatory brain potential suggests a relatively stronger involvement of fronto-central motor regions for *requests*, which may reflect the speaker's expectation of the partner actions typically following *requests*, e.g., the handing over of a *requested* object. Our results indicate that different neuronal circuits underlying the processing of different speech act types activate already before speaking. Results are discussed in light of previous work addressing the neural basis of speech act understanding and predictive brain indexes of language comprehension.

2.1 Introduction

When humans speak, they are driven by a wide variety of communicative goals and intentions. Words and sentences are used as tools for making recommendations, expressing invitations, for asking someone for help or support, for *requesting* an object or for *naming* it (Austin, 1962; Searle, 1969; Wittgenstein, 1953). Experimental linguistic research addressing speech production has so far mainly focused on the picture naming paradigm (or variations thereof), where participants have to *name* the object depicted in a line drawing shown on a computer screen (Abdel Rahman & Melinger, 2019; Miozzo et al., 2015; Strijkers et al., 2017; Strijkers et al., 2010). This somewhat artificial paradigm is simple and easily administered. However, it is clear that the variability of communicative functions relevant in everyday language use is not appropriately covered when exclusively addressing *naming*, in particular in a computer-controlled experimental paradigm. Here, we focus on this variability of communicative function as it occurs in more natural ways of using language, by comparing two different speech act functions: *naming* and *requesting* an object between two partners. We ask specifically whether neurophysiological indicators recorded from the human brain discriminate between these speech acts during real social interactions and at which point in time any difference can first be recorded.

Previous neurocognitive research has reported brain correlates of communicative functions in speech and language comprehension (Bašnáková et al., 2015; Bašnáková et al., 2014; Egorova et al., 2014; Egorova et al., 2013, 2016; Gisladottir et al., 2018; Gisladottir et al., 2015; Tomasello et al., 2019; van Ackeren et al., 2012; van Ackeren et al., 2016). Results indicate that comprehension of speech act types, such as direct or indirect speech acts, or *naming* and *requesting*, have distinct brain correlates, even if they are conveyed by exactly the same words. These preexisting results raise the question whether the brain signatures distinguishing between speech act types are specific to the comprehension modality or rather general, thus persisting equally during production and comprehension of speech and language. Brain language theories, along with psycholinguistic models, make different predictions here. Modular and so-called stream models claim at least partly separate processing components for speech production and perception/comprehension interlinked by way of interfaces (Hickok & Poeppel, 2007; Indefrey, 2011; Indefrey & Levelt, 2004; Levelt et al., 1999), thus implying that different brain areas contribute to speech production and understanding. In contrast, integration models claim that the same cognitive and brain mechanisms are at work when people use and understand language, although these models of course cannot be reduced to this claim, but include many more specific claims about spatiotemporal activation patterns at work in different ways during speaking and understanding (Pickering & Garrod, 2013; Pulvermüller, 1999, 2018; Pulvermüller & Fadiga, 2010; Strijkers & Costa, 2016). This leads to the prediction that speech production and understanding activate similar and strongly overlapping brain regions. Furthermore, at present, only a small minority of models explicitly take into account the mind and brain basis of communicative processes, thus allowing for strong predictions on pragmatic brain processes and, in particular, differences between speech act types (e.g., Pickering & Garrod, 2013; Pulvermüller et al., 2014). Here, we give a brief overview of recent work on communicative function processing and then outline an experiment addressing the mechanisms of communicative function processing in speech production.

Recent neurophysiological studies documented rapid or near-instantaneous brain-correlates of understanding of pragmatic information of communicative functions within the first 200 msec after presentation of critical communicative stimuli (Egorova et al., 2014; Egorova et al., 2013; Tomasello et al., 2019). Multiple brain areas were involved in distinguishing the processing of different speech act types, for example, direct versus indirect speech acts (van Ackeren et al., 2012; van Ackeren et al., 2016) or assertive (e.g., *statements*) versus directive ones (e.g., *requests*, Egorova et al., 2016; Tomasello et al., 2019). In particular, when comparing the speech acts of *naming* and *requesting* objects from a partner, a consistent finding is the involvement of hand motor cortex in *request* understanding (Egorova et al., 2016; Tomasello et al., 2019; van Ackeren et al., 2016). This specific motor area activation can best be explained by the action-related nature of *request* function. According to linguistic pragmatic theories (Alston, 1964; Fritz, 2013; Fritz & Hundsnurscher, 1994; Hamblin, 1970; Kasher, 1988), a specific speech act is embedded in an action sequence tree comprising the sequence of other (speech) acts that typically and regularly precede and follow it. In this framework, *requesting*-an-object, via its specific action sequence structure, is firmly associated with the action of the partner grasping an object and handing it over to the speaker, and, as alternative follower actions, with the *denial* or *rejection* of the *request.* In contrast, the action sequence following *naming*-an-object would normally not be followed by overt object-oriented actions, or *denial* or *rejection* of such a response. Other unspecific responses to speech acts, such as *asking back*, *correcting* the utterance or *approving* it, are shared by *naming* and *request* and by most other communicative actions. Hence, the stronger activation of motor areas for *requests* may reflect the additional processing of the relatively richer knowledge about possible partner actions, which does not come into play in understanding *naming* actions. On this background, integration models predict that also in production of speech acts, the same differences between the brain signatures of *requests* and *naming* actions will emerge, with motor areas being relatively more strongly active. In contrast, brain language models implicating largely different production and understanding mechanisms do not predict such a commonality.

To appropriately address the brain signatures of speech act types in speech production, it is essential to choose an experimental paradigm where the same linguistic forms are used to perform different communicative acts. Otherwise, any differences between utterance forms might confound any distinctions in brain activation between speech acts. To facilitate the task of finding identical forms for different communicative functions, single words were chosen, as they are the most elementary means to perform speech acts (Dore, 1975; Wittgenstein, 1953). A noun such as "coffee" can be used to *request* a cup of coffee, to *ask for information* (e.g., whether there is coffee on the menu) to *name* the content of a mug or to *inform* about it. What these communicative functions have in common is the propositional content, namely the things and issues they are about, e.g., in this case that they are used to speak about coffee rather than, for instance, tea. However, crucially, they differ in their communicative or speech act function (illocutionary force), that they are used to *request* or *name* (Austin, 1962; Searle, 1969). We measured event-related brain potentials as the same real objects were *named* and *requested* by the participants by using the same single words. Also the communication partner, the objects available and the general arrangement of the communicative context were the same between the two conditions. Note also that a paradigm was chosen that approximates natural social communicative interaction by establishing a dialogic language game context involving the speaker and a partner. To situate both speech act conditions in a context as natural as possible, participants were instructed to imagine the *requests* to take place between a merchant and a customer and the *naming* between an examiner and a testee.

We recorded event-related brain potentials continuously during social-communicative *request* and *naming* interactions and, in the evaluation, focused on a time interval already starting 2000 msec before the onset of speech production. This focus on anticipatory activity had the following reasons. First, overt speech production is accompanied by muscle movements which cause muscle artifacts in the recordings of brain responses (see e.g., Miozzo et al., 2015; Strijkers et al., 2017). Before speech onset, these artifacts are absent or much reduced. Second, it is well known that, before overt movement onset, there are brain indicators of processes of planning, decision and motor control, which are most pronounced in prefrontal, premotor and motor areas. Such anticipatory motor activity known under the label of the 'Readiness Potential' or the 'Bereitschaftspotential' has been documented for movements with different parts of the body (e.g., Di Russo et al., 2017; Kornhuber & Deecke, 1965b) and for speech, too (Deecke et al., 1986; Galgano & Froud, 2008; Gunji et al., 2000). Third, and most importantly, anticipatory slow waves have also been recorded during visual or acoustic perception of actions (Grisoni et al., 2016; Kilner et al., 2004) and in word and sentence comprehension (Grisoni et al., 2017; Grisoni, Moseley, et al., 2019, for a review see Pulvermüller and Grisoni, 2020). Intriguingly, these anticipatory potentials reflect aspects of the meaning of the upcoming sounds or words. Therefore, they can be considered predictive brain activity providing semantic information and are called 'semantic prediction potential'.

We hypothesized that in contexts where pragmatic function of upcoming speech acts is predictable, (i) a similar anticipatory potential as documented for semantic prediction in sentence comprehension (for a review see Pulvermüller & Grisoni, 2020) would appear prior to speech act production,(ii) different predictive brain indexes appear for different speech act functions, (iii) stronger anticipatory neural sources will emerge for *request* compared to *naming* and (iv) this additional activity for *request* relative to *naming* production resembles that previously seen during the comprehension of *requests* relative to *naming* actions, including activation in sensorimotor brain regions (see e.g., Egorova et al., 2016; Tomasello et al., 2019).

2.2 Materials and Methods

2.2.1 Participants

Twenty-five healthy volunteers (12 females, 13 males) were paid for their participation in the experiment. Our sample size was determined on the basis of a power analysis performed in G*power 3.1.9.7 (Faul et al., 2007). To this scope, we took the effect size from Tomasello et al. (2019) which investigated the same two speech acts (*naming* and *request*) with the same method (EEG) used in the current study, but in the comprehension modality. Thus, in order to achieve an effect size of $\eta_p^2 = 0.29$ (Tomasello et al., 2019) with $\alpha = 0.05$ and $power = 0.8$, we determined that minimum sample size of 23 subjects was required, to which we recorded two more subjects in order to compensate for potential subjects exclusion. All subjects were monolingual German native speakers and between 18 and 35 years old (mean age 24.7 years ± 3.9 SD). Subjects reported no neurological disorders or reading/writing disorders and had normal or corrected-to-normal vision. They were all right-handed, as assessed using the Edinburgh Handedness Inventory (Mean laterality quotient = 83.5 ± 15.3 SD) (Oldfield, 1971). The above mentioned inclusion and exclusion criteria were defined prior to study conduction. All procedures were approved by the Ethics Committee of the Charité Universitätsmedizin, Campus Benjamin Franklin (Berlin, Germany) and were in agreement with the Declaration of Helsinki. All participants were paid for their participation and signed an informed consent form prior to the beginning of the experiment.

2.2.2 Stimuli and procedures

The experimental material consisted of 96 real physical objects that were selected to be small and graspable. We specifically took care that all items were familiar and typical of everyday life situations. Naming consistency was confirmed by the tested population (see 'Audio Processing' section below). The object stimuli were split into two different lists, such that their verbal labels, which were one or two syllables long, were matched for the following lexical and sub-lexical psycholinguistic variables: normalized lemma frequency, number of syllables, number of sounds, number of consonants at word onset and normalized bigram and trigram frequency. The normalized lemma frequency was taken from two different databases of German language: the dlexDB (Heister et al., 2011) and the SUBTLEX-DB database (Brysbaert et al., 2011). The dlexDB database is based exclusively on written German material and therefore is representative of written language only. For this reason, we also included a measure of normalized lemma frequency from the SUBTLEX-DE, which is based on German movie subtitles reflecting spoken German language. Independent sample t-tests failed to indicate any significant differences between the two stimuli lists on any of the aforementioned variables (for details, see Table 2.1).

	List 1		**List 2**				
Variable	**Mean**	**SEM**	**Mean**	**SEM**	**t-value**	**df**	***p***
Norm. Lemma Frequency (SUBTLEX-DB)	14.41	2.56	14.41	2.31	<0.01	94	0.99
Norm. Lemma Frequency (dlexDB)	14.53	2.15	16.74	2.51	<0.01	94	1
Norm. Bigram Frequency	473407	37018	466735	37199	<0.01	94	0.90
Norm. Trigram Frequency	204488	13669	221186	16906	0.76	94	0.45
Number of Syllables	1.73	0.06	1.73	0.06	<0.01	94	1
Number of Sounds	4.81	0.14	4.81	0.17	<0.01	94	1
Number of Consonants at Word Onset	1.31	0.08	1.31	0.09	<0.01	94	1

Table 2.1: Matching of the two lists of experimental words for psycholinguistic variables. Average values as well as the standard error of the mean (SEM) are shown for each measure and for both lists, together with the results of independent sample t-tests, including t-value, degrees of freedom (df) and error probability (p).

2.2.3 Familiarization phase

In order to increase naming consistency of the objects used for the main experimental task (i.e., *naming* and *requesting* a desired objects), subjects were familiarized with the object stimuli and their labels prior to the main experimental task. To this end, a color photography of the objects with the appropriate label written in white font and capital letters on a light grey background, was shown to the subjects for two seconds in the middle of the screen (LCD U2412Mb, Dell inc, Round Rock, TX). The order of the items was randomized. The stimulus presentation was controlled by PsychoPy2 software (Peirce, 2007). The subjects were instructed to pay attention to the images and labels, but not specifically to try to remember them.

2.2.4 Main experimental task

The main experimental task was divided into two blocks, respectively corresponding to the *naming* or to the *requesting* condition and each including 48 trials. The participants' task was to *name* or *request* a self-selected item presented on the table by interacting with a confederate which, known to the participant, was a member of the research team. We attempted to match the two conditions in several respects, including the social-communicative context, the actual setting including the persons, objects and basic actions relevant in it and the linguistic tools used. In the *naming* condition, participants were instructed to imagine that they were taking part in a language test by interacting with an examiner, who assessed whether the real objects lying on the table were correctly *named* by the testee (with overt feedback being given only at the end of the task). In contrast, in the *requesting* condition, participants were asked to imagine that they were interacting with a salesman and, as customers, would have to *request* the items for purchase. Both scenarios were kept as simple as possible to avoid any confound for situational complexity between *naming* and *request* contexts. In both conditions, participant and confederate were sitting on opposite sides of a table. At the beginning of the first trial of each block, two objects were placed on the table. After an auditory signal was given (trial onset signal), the participant had to mentally select one of the two items present on the table, then fixate their gaze on a red dot located at the center of the table so that neurophysiological responses (e.g., related to object selection) could return to baseline, and finally, after an additional self-determined interval of few seconds (and still while gazing at the red dot), *request* or *name* the object using a one-word utterance, for example *"Schere"* (=scissors). Subjects were specifically instructed to avoid the use of any other verbal materials, including articles or politeness expressions such as "Please" or "Thank you". Notice that no time constraint was given to the participants regarding the onset of their speaking. The subsequent reaction of the confederate differed between the two conditions. In the *naming* condition, the *named* object was removed from the table, placed in a basket not visible for the subject and replaced by another object. In the *request* condition, the *requested* object was also removed from the table and placed into a basket that was not visible for the subject, but in this case the basket had previously been designated as "the subject's basket". Just as in the *naming* condition, the *requested* object was subsequently replaced by a new one. Crucially, the trial structure was precisely the same for both conditions prior to and during the subject's utterance. The only difference was in the location where the object was placed by the confederate after it had been *named* or *requested* (Figure 2.1). The order of conditions, as well as the assignment of the object stimulus list to one or the other condition, was counterbalanced across participants. Thus, each object stimulus was presented only once to each subject to avoid potential repetition effects known to reduce the cortical responses of repeated stimuli (Grill-Spector et al., 2006; Nagy & Rugg, 1989). The presentation order of the objects within a block was managed as follows: all the items in one block were divided into four sets or "bags" that were counterbalanced for the aforementioned psycholinguistic variables. The order in which the bags were taken was randomized and the presentation of the object that were in each bag was varied across subjects. The side of the body (namely the left or right hand) with which the confederate performed her object manipulation responses was counterbalanced across subjects. Namely, for the first half of the subjects, the items were always replaced by the confederate with her right hand, whereas for the second half, they were replaced by the confederate's left hand. The subject's basket in the *request* condition and the location where the objects were put in the *naming* condition were at opposite sides of the subject and were inverted for half of them. Notice that at every trial, two objects were always present on the table, and one of them could remain on the table for several trials if not *named/requested* immediately by the subject. Moreover, as always one out of two objects had to be chosen, it followed that on the final trial of every block, a last single item was left. This last item was not subject to *naming/request* and subsequently removed.

In total, each subject performed 94 trials, one with each of the 2 x 48 objects minus the final single left-over ones. One block had an approximate duration of 20 min resulting in a total experiment duration of about 45 min, including a ca. 5 min break between blocks. In order to determine the voice onset of the produced utterances, during the entire experiment, the voice of the participants was continuously recorded via a high-resolution microphone (SM58, Shure, Stuttgart, Germany) placed at a distance of approximately 70 cm from the subject's mouth.

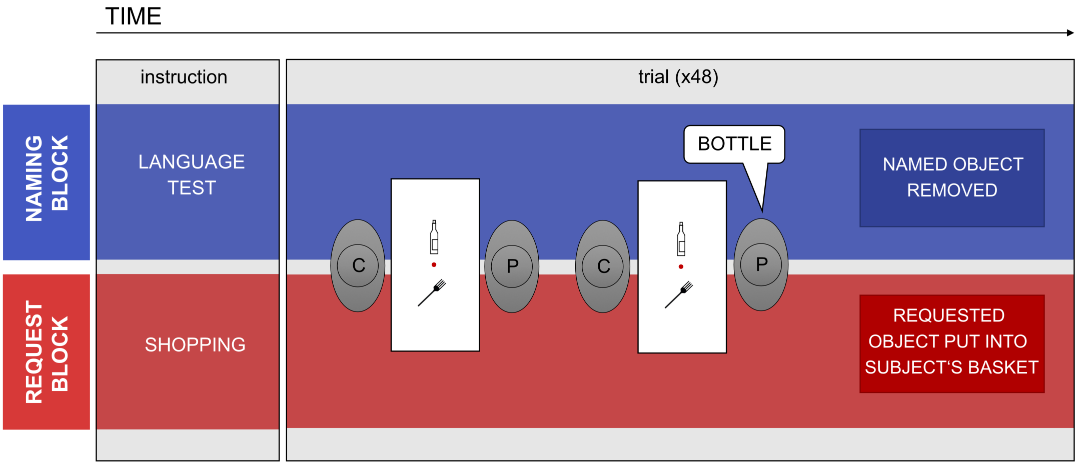


Figure 2.1: Schematic representation of the structure of experimental blocks in the *naming* and *request* conditions. In both conditions, confederate (C) and participant (P) are each sitting at opposite sides of a table. Before the beginning of the *naming* block (top Panel, in blue), participants were instructed to imagine that they were in a testing room partaking in a language test interacting with an examiner. The beginning of each trial was signaled by an acoustic tone (a pure tone of 500 Hz). From that moment on the participant could choose one of the two real objects on the table, fixate the red dot on the table for a few seconds, and then *name* the item of their choice. Finally, the *named* object was removed by the confederate and replaced by a new one. Before the beginning of the *request* block (bottom Panel, in red), participants were instructed to imagine that they were in a shop, interacting with a salesman. Precisely as in the *naming* condition, the beginning of each trial was signaled by the acoustic tone. From that moment on, the participant chose one of the two objects on the table, fixated the red dot on the table for a few seconds, and then *requested* the item of their choice. Finally, the *requested* object was put into the participant's basket, and a new object was placed on the table.

2.2.5 Audio processing

The time of voice onset was determined off-line by visually inspecting the waveforms from the audio recording using Audacity 2.1.1 software (https://sourceforge.net/projects/audacity/). The obtained markers were then temporally aligned with each subject's EEG signal. The trials were ascribed to five different categories based on the subject's responses and coded as follows:

- Correct: trials where the subject uttered exactly the target word, i.e., the exact same label that was associated with the specific object in the familiarization task.

- Synonymous: trials where subjects uttered synonymous words, e.g., *"Schüssel"* instead of *"Schale"* (=bowl) or a compound word derived from the correct word, e.g., *"Briefumschlag"* (=postal envelope) instead of simply *"Umschlag"* (=envelope).

- Incorrect: in these categories were put all labels that were non-synonymous relative to the correct label, e.g., *"Schachtel"* (=box) instead of *"Seife"* (=soap) also when they were semantically related, e.g., *"Blume"* (=flower) instead of *"Pflanze"* (=plant).

- Mispronounced: trials where the subject seemingly intended to utter the correct word, but produced a mistake in the pronunciation, e.g., *"Harken"* instead of *"Haken"* (=hook).

- Invalid: trials that were not performed at all because of technical problems in the experimental procedure.

Trials entered the EEG analysis only if they were classified as correct, based on the above-mentioned criteria. The average correct rate per subject in the two conditions collapsed was 95.1%. No statistical differences in the correct rate between *naming* (95.2%) and *requesting* (95.0%) condition were detected by paired t-test ($t(24) = 0.22$, $p = 0.82$).

2.2.6 EEG recording

The EEG was recorded in an electrically and acoustically shielded chamber through 64 active electrodes embedded in a fabric cap (the green and yellow subsets of electrodes from the actiCAP 128Ch Standard-2; Brain Products GmbH, Munich, Germany). These were arranged according to the 10-10 conventional layout with the following modifications: the reference was moved from FCz position to the tip of the nose, the electrode occupying the PO10 position replaced the empty FCz position. The PO9 and FT9 electrode positions were reassigned as EOG channels placed below and above the left eye respectively and the FT10 electrode to the right outer canthus to measure the vertical and horizontal electro-oculograms. All electrodes were referenced to an electrode placed on the tip of the nose. Data were amplified and recorded using the Brain Vision Recorder (version: 1.20.0003; Brain Products GmbH), with a passband of 0.1-250 Hz, sampled at 500 Hz and stored on disk. Impedances of all active electrodes were kept below 10 KΩ.

2.2.7 EEG data preprocessing

The EEG data were processed with the EEGlab 14.10b (Delorme & Makeig, 2004) and the Fieldtrip (version 2018.04.17 Oostenveld et al., 2011) toolboxes for Matlab (2014, The MathWorks Inc., Natick, MA, 2000). Data were down-sampled at 250 Hz and band-pass filtered at 0.1-30 Hz. The signal from the upper and lower eye electrodes was used to generate bipolar vertical EOG signals and from the average of the latter two minus the potential at the right outer canthus was computed to produce the horizontal EOG. Noisy EEG channels were removed from each dataset after visual inspection. Independent component analysis (ICA) was carried out based on the standard algorithm included in the EEGlab toolbox and was set to generate 35 independent components from the EEG data. The resulting independent components were identified as artifactual using two procedures. First, we identified components that captured eye movements as those correlating ($|R| > 0.3$) with either of the previously generated horizontal and vertical EOG channels and removed them from the data to minimize eye-related artefacts (Groppe et al., 2009; Hanna et al., 2014; Hanna & Pulvermüller, 2014; Tomasello et al., 2019). Second, we identified the component capturing articulatory activity as the ones that correlated ($|R| > 0.3$) with the signal of any of the channels FT7, FT8 or the lower EOG channel. These three electrodes were the ones that were most likely to be affected by articulatory artifacts due to their location on top of the temporal muscles and relatively close to the mouth, respectively. The components that were marked as artifactual were subtracted from the EEG data. In average, 3.2 (range: 2-6) out of 35 components were removed from each participant's dataset because of ocular activity and 3.3 (range: 2-6) because of articulatory activity. The previously removed EEG channels were interpolated based on the standard EEGlab toolbox method. Subsequently, the data were segmented into epochs starting at -2000 msec prior to voice onset (VO) and ending at 500 msec after it (Figure 2.2, Panel A). Thus, data were epoched in a response-locked fashion. Baseline correction was applied subtracting from the data the average voltage of a 200 msec time window between -2000 and -1800 msec relative to VO. This was done because we expected the anticipatory activity to resemble the Readiness Potential, RP, which typically starts < 1 sec before movement onset (Di Russo et al., 2017; Kornhuber & Deecke, 1965b). An artefact rejection procedure was applied only in the time window -2000 msec to VO. We focused on the time range before VO, as this is where any relatively uncontaminated anticipatory activity may occur (Grisoni et al., 2016; Grisoni et al., 2017; Grisoni, Moseley, et al., 2019; Kornhuber & Deecke, 1965b; Shibasaki & Hallett, 2006). Trials were rejected if their potential exceeded ±150 μV, a threshold chosen based on previous speech production studies (Aristei et al., 2011; Rose et al., 2019; Strijkers et al., 2010). In the current dataset, the average trial rejection rate per subject across collapsed conditions was 3.6%. The trial rejection rate was comparable between conditions as assessed by paired t-test ($t(24) = -0.21$, $p = 0.84$). Only subjects with a trial rejection rate $< 20\%$ in both conditions were included in the analysis. Following this criterion, one subject was excluded from the final analysis. Additionally, one subject was excluded because, when collapsing the two conditions, his average ERP measured between -2s and VO was beyond ±2.5 SD from the grand-average for at least 10% of the time points. A third subject was excluded because of the two above mentioned criteria combined with self-reported illness on the testing day. Overall, twenty-two subjects out of twenty-five entered the final EEG analysis. An additional set of analyses was also computed with a more conservative artifact rejection criterion of $\pm 100\ \mu$ V to further ensure that any significant differences between brain responses were not affected by artifacts (for more detail see Appendix A).

With the aim to estimate muscular activity recorded during the task, we performed an additional separate analysis of the neurophysiological data. As the spectral power of muscular activity (e.g., from articulators) increases with frequency (especially above 20 Hz), whereas that of the EEG signal decreases with frequency and is relatively low above the beta range (Cacioppo et al., 1990; Goncharova et al., 2003; Pulvermüller et al., 1997), the raw neurophysiological data, after downsampling to 250Hz, were high-pass filtered at 20 Hz. Subsequently, the data were epoched and baseline corrected with the same parameters as in the main analysis, followed by a full-wave rectification and by the calculation of the upper envelope on an individual trial basis. Finally, grand-averages of the pooling of the same EEG channels used for the cluster-based permutation test (Figure 2.2, Panel D) were calculated separately for *naming* and *request* condition. The resulting grand-average is an estimation of the strength and temporal unfolding of (mainly) muscular activity prior to word generation (see Figure 2.2, Panel B).

2.2.8 ERP data analysis

To determine any differences in amplitude and peak latencies between the two conditions (*naming* and *requesting*) and to avoid the problem of multiple comparisons, a first statistical analysis was performed using a (non-parametric) cluster-based permutation test (Maris & Oostenveld, 2007; Sassenhagen & Draschkow, 2019) as implemented in the FieldTrip toolbox. As the readiness potential (RP) typically occurs about one second prior to speech onset and is largest on the fronto-central-parietal electrodes (Kornhuber & Deecke, 1965b; Shibasaki & Hallett, 2006), we centered our analysis on the time period between -1000 msec and VO and restricted it to 45 frontal, central and posterior electrodes (Frontal: F7, F5, F3, F1, Fz, F2, F4, F6, F8, FC5, FC3, FC1, FCz, FC2, FC4, FC6, Central: T7, C5, C3, C1, Cz, C2, C4, C6, T8, CP5, CP3, CP1, CPz, CP2, CP4, CP6, Posterior: P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, POz, PO8) (see Fig. 2D). This cluster-based permutation test was computed by randomly exchanging data between the two stimulus conditions and producing the maximal positive and negative cluster of each permutation (5000 permutations). In addition, we repeated the same test in a smaller time window going from -1000 to -200 msec before VO, thus excluding the last 200 msec of the previous analysis that may have been contaminated by articulatory artefacts as a previous study reported articulatory movement proceeding voice onset by ca. 200 msec (Fargier et al., 2018; Salmelin, 2010, p. 143). Furthermore, we ran the same permutation test analysis on the vertical and horizontal EOG channels to ensure that no significant differences were present between the two conditions in the signals recorded from ocular responses electrodes. All cluster-based permutation tests were considered significant only if clusters with $p < 0.025$ two-tailed were found, thus resulting in a critical $\alpha = 0.025$ corresponding to a false alarm rate of 0.05.

The aforementioned cluster-based permutation tests were complemented with a repeated-measures analysis of variance (ANOVA), which allowed a more fine-grained analysis of the temporal and spatial extent of the effects. Hence, 36 channels (see Figure 2.2, Panel D) were grouped to form the following pools depending on their scalp location and their relation to the factors of laterality and gradient: left anterior (LA: F7, F5, F3, FC5) midline anterior (MA: F1, Fz, F2, FCz), right anterior (RA: F4, F6, F8, FC6), left central (LC: T7, C5, C3, CP5), midline central (MC: C1, Cz, C2, CPz), right central (RC: C4, C6, T8, CP6), left posterior (LP: P7, P5, P3, PO7), midline posterior (MP: P1, Pz, P2, POz) and right posterior (RP: P4, P6, P8, PO8). Additionally, the mean voltage before voice onset was averaged within five 200 msec time windows (TW1: -1000 to -800 msec, TW2: -800 to -600 msec, TW3: -600 to -400 msec, TW4: -400 to -200 msec, TW5: -200 to 0 msec). Thus, the ANOVA included the following within-subject factors: Communicative act [two levels: *naming* and *request*], Laterality [three levels: left, midline and right], Gradient [three levels: anterior, central and posterior], Time window [five levels: TW1, TW2, TW3, TW4, TW5]. Furthermore, to test for any difference in neurophysiological activity across time during the experiment, we ran a 3-way ANOVA that included the factors Communicative act [two levels: *naming* and *request*], Time window [five levels: TW1, TW2, TW3, TW4, TW5] and Exposure time [two levels: first vs second experimental block]. This analysis also addressed the issue of whether there might have been any differences between speech act conditions across the experiment - for example greater fatigue effects in one condition than in the other. In addition, to test if the side of the confederate response action (who used either the left or right hand when manipulating the objects) was reflected in the topographies of the brain responses, we repeated the main ANOVA analysis, with the addition of the between-subject factor Confederate Response Hand [two levels: left and right hand]. Finally, a 2-way repeated measures ANOVA with factors of Communicative act [two levels: *naming* and *request*] and time window [five levels: TW1, TW2, TW3, TW4 and TW5] was run on the horizontal and vertical EOG channels to explore whether any statistically significant EEG differences between conditions found at scalp channels could possibly be due to the differences in ocular activity. Greenhouse-Geisser correction (Geisser, 1959) was applied to the degree of freedom whenever violation of the sphericity assumption occurred. Corrected p-values, along with epsilon (ϵ) values are reported throughout. Partial eta-square (η_p^2) values are also stated, which is defined as an index of effect size ($0.01 - 0.06$: small; $0.06 - 0.14$: medium; > 0.14: large; Cohen, 1988).

2.2.9 Source level analysis

To localize the cortical origin of the neurophysiological responses of *naming* and *request* functions before speech onset, we performed a distributed cortical source analysis. Source solutions were calculated on the grand-averaged responses that benefit from higher signal-to-noise ratio (SNR, see, e.g., Egorova et al., 2013; Hauk et al., 2006; Shtyrov, 2011). Also, they were restricted to those latencies where significant effects between speech act conditions (i.e., -600 msec to voice onset) were found in the statistical analysis of event-related potentials calculated relative to their baseline at -2200 to -2000 msec to voice onset. In addition, to further examine if the two conditions differed in terms of the involved sources, we obtained the difference source maps by computing the subtraction between the resulted brain sources of *naming* and *request*. We used the structural MRI included in SPM12 to create a cortical mesh of 8196 vertices. The volume conductors were constructed with an EEG (3-shell) boundary element model. The method used for source estimation was the multiple sparse prior (MSP) technique, specifically the "greedy search" algorithm (Litvak et al., 2011), which had previously been used in our laboratory (e.g., Grisoni et al., 2017; Tomasello et al., 2019). Activation maps were then smoothed using a Gaussian kernel of FWHM 12 mm. Each region emerged from the sources were reported with their respective cortical labels.

2.2.10 Acoustic analysis

To test whether differences in the RP component between *naming* and *requesting* were driven by differences in articulatory preparation of speech execution, we performed additional analysis on the produced utterances. The acoustic profile of the vocalizations was quantified in terms of duration (msec), loudness (RMS, dB), pitch (F0, Hz), jitter (ms), shimmer (dB) and harmonic-to-noise ratio (HRN, dB). To this end, the software PRAAT 6.0.49 (http://www.praat.org) was used to compute the mean average of the acoustic proprieties mentioned above. Later the generated values were averaged across all vocalizations produced during *naming* and *request* contexts, resulting in two values for each participant. Finally, the Wilcoxon signed-rank tests were used to statistically compare the acoustic properties of the produced words between *naming* and *requesting* functions across subjects.

2.3 Results

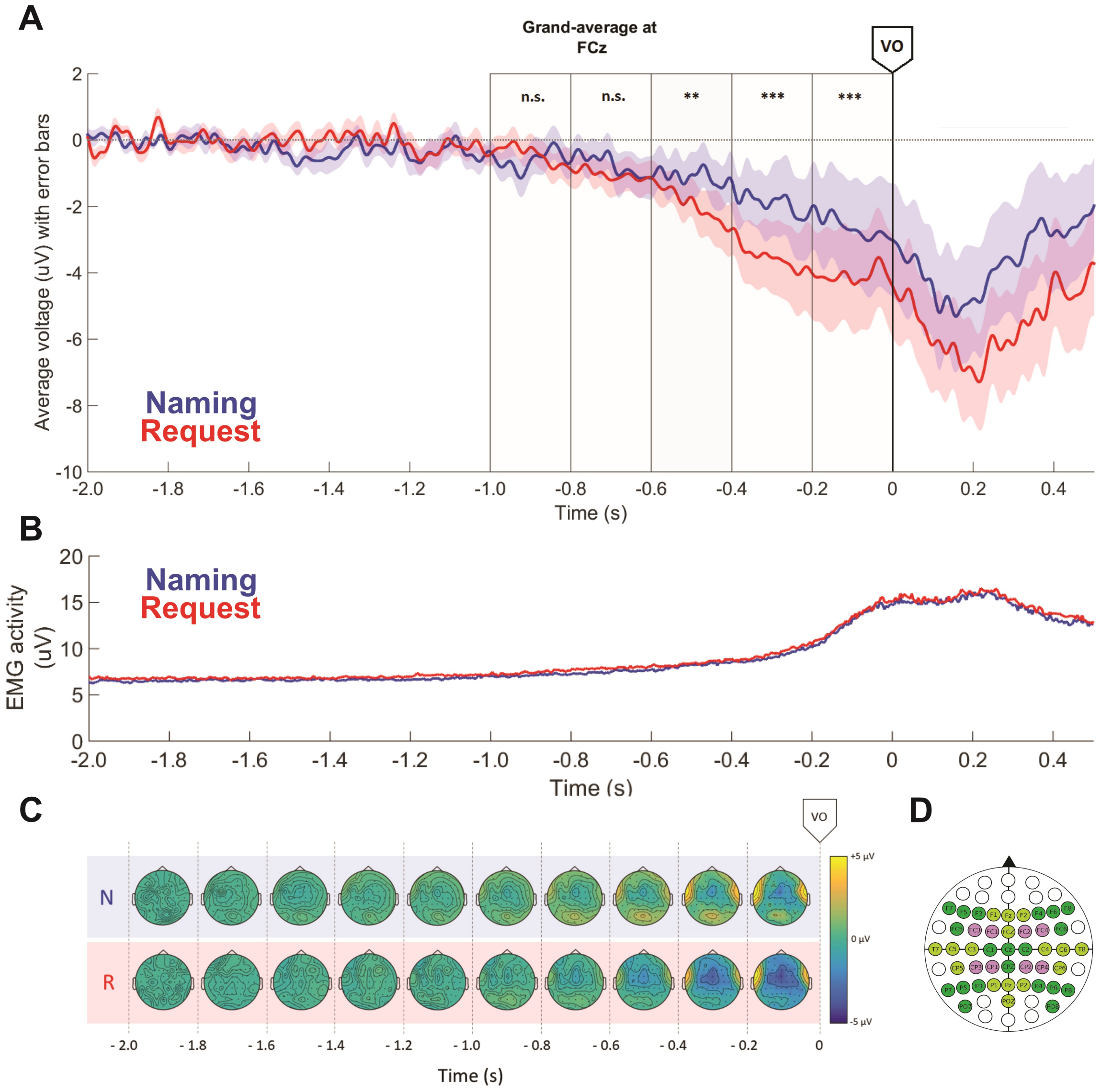
2.3.1 Cluster-based permutation tests on ERP data

Figure 2.2, Panel A illustrates the grand average recorded at the mid-frontocentral electrode FCz in the *naming* (in blue) and *request* (in red) conditions. Visual inspection of the ERPs shows overall more pronounced negativity for *requests* compared to *naming*. Figure 2.2, Panel C, illustrates the scalp distribution of the ERPs for *naming* and *requesting*, time-locked to the VO. Visual inspection of these topographies shows that both conditions are characterized by progressive negativity building up at central electrodes locations. To test for significant differences between *naming* and *request* conditions, we performed cluster-based permutation tests on the large time-window from -1000 msec to VO and across the previously defined pool of frontal, central and posterior electrodes (see Section 2.2.8, "ERP Data Analysis" and Figure 2.2, Panel D for more details). The test detected a statistically significant difference between the *naming* and *requesting* condition ($p = 0.003$, with significance threshold adjusted for two-tailed comparisons to $p < 0.025$). The difference between conditions was most pronounced in the time window between about -430 msec to about -130 msec relative to VO. The same analysis performed on the smaller time window from -1000 to -200 confirmed the previous results ($p = 0.003$, with significance threshold adjusted for two-tailed comparisons to $p < 0.025$) by revealing differences most pronounced in the time window from -430 msec to the end of the tested time window (i.e., -200 msec). To ensure that the significant differences between the two conditions could not be due to differences in ocular activity, we performed two additional permutation tests on the horizontal and vertical EOG channels, respectively. These did not reveal any significant differences between *naming* and *requesting* condition in the hEOG (no clusters found) and vEOG responses (all clusters with $p > 0.129$, with significance threshold adjusted for two-tailed comparisons to $p < 0.025$).

2.3.2 rmANOVA on ERP data

The cluster-based permutation tests were complemented by a 4-way repeated measure ANOVA (Communicative act x Laterality x Gradient x Time Window) performed on the neurophysiological brain responses of *naming* and *request* functions during speech preparation. This analysis revealed a significant main effect of Communicative act ($F(1, 21) = 7.06$, $p = 0.015$, $\eta_p^2 = 0.25$) with *requesting* being associated overall with a greater negativity compared to *naming* functions and a significant two-way interaction between Communicative act and Time window ($F(4, 84) = 5.39$, $\epsilon = 0.44$, $p = 0.011$, $\eta_p^2 = 0.20$). The significant interaction was confirmed by post-hoc tests (Bonferroni-corrected for 5 comparisons) showing that

Figure 2.2: (A) Grand average event-related potentials (ERP) measured prior to the onset of *naming* (blue) and *request* (red) actions with standard error of the mean (SEM) being indicated by the lighter shade of the respective color. Recordings are from the mid-fronto-central channel FCz. The X axis represents time in seconds before and after voice onset (VO) and the Y axis represents the ERP amplitude in micro-Volt (μV). The grayed areas indicate the time windows where the difference between *naming* and *request* were significant (after Bonferroni-corrected post-hoc tests), as well as their respective significance levels. (B) EMG activity measured pooling the same channels that were used for the cluster-based permutation test. (C) ERP topographies for *naming* and *request* trials from -2000 msec to VO, given as maps each displaying average potentials in time windows of 200 msec. Each map shows the head and recording array from above, with the nose pointing upward. (D) Electrodes used in the ANOVA (poolings indicated in bright and dark green) and for the cluster-based permutation test (electrodes indicated in bright and dark green and purple electrodes).

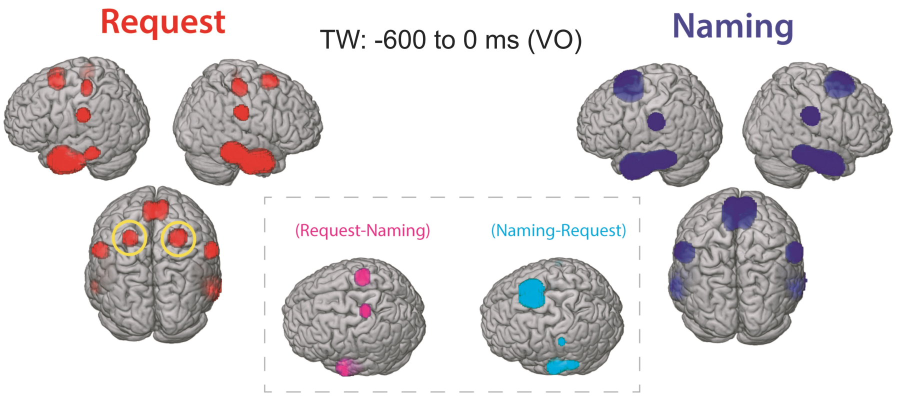


the differences between *naming* and *requesting* conditions were specific to the three last tested time windows (TW3: -600 to -400 msec, $p = 0.002$; TW4: -400 to -200 msec, $p < 0.001$; and TW5: -200 to 0 msec, $p < 0.001$) (see Figure 2.2, Panel A). Furthermore, the repeated measures ANOVA revealed a significant interaction effect between the topographical factors of Laterality and Gradient ($F(4, 84) = 3.30$, $\epsilon = 0.49$, $p = 0.048$, $\eta_p^2 = 0.14$), which was due to the frontocentral maximum of the negativity and polarity reversal at posterior electrodes (see Figure 2.2, Panel C). Post-hoc tests (Bonferroni-corrected for 9 comparisons) showed that along the midline, the negativity was greatest at anterior ($p < 0.001$) and central ($p < 0.001$) electrode pools compared to the posterior pool. No further statistically significant differences were detected between anterior, central and posterior pools in the left or right hemisphere.

The 5-way mixed design ANOVA (Communicative act x Laterality x Gradient x Time Window x Confederate response hand) conducted to investigate any significant effects of the hand used by the confederate to perform the response, showed no significant main effect of Confederate response hand ($F(1, 20) = 0.02$, $p = 0.887$). Also, no significant interactions of Confederate response hand with Communicative act ($F(1, 20) = 0.17$, $p = 0.688$) or with Communicative act and Time window ($F(4, 80) = 1.27$, $\epsilon = 0.42$, $p = 0.290$) were detected. Similarly, the 3-way mixed ANOVA (Communicative act x Time window x Exposure time) performed to test for any effects of frequent repetitions or habituation across the experiment and, importantly, for any differential repetition effects relatively more manifest for one of the communicative actions, did not show any significant main effect of Exposure time ($F(1, 20) = 0.20$, $p = 0.658$) or interaction with Communicative act ($F(1, 20) = 0.01$, $p = 0.929$) or with Communicative act and Time window ($F(4, 80) = 0.69$, $\epsilon = 0.45$, $p = 0.495$).

Similar to the cluster permutation tests, we ran two additional 2-way repeated-measures ANOVAs (Communicative act x Time window) on the horizontal and vertical EOG channels respectively to test for any possible significant differences in the ocular EOGs activity between the two conditions. However, no significant differences were found between *naming* and *request* functions either in the horizontal ($F(1, 21) = 0.08$, $p = 0.784$) or in the vertical EOG ($F(1, 21) = 1.22$, $p = 0.281$). Finally, visual inspection of the EMG activity (Figure 2.2, Panel B) revealed that muscular activity might have been manifest starting around 200 msec before voice onset. However, the time course of the measured EMG was virtually identical in the two conditions on the entire time window.

Figure 2.3: Source analysis results for *request* (in red) and for *naming* (in blue) computed in the time window going from -600 msec to voice onset, where significant differences between conditions were found. Notice the additional fronto-central activation highlighted in yellow for the *request* function. The box indicates the resulting difference brain source maps of *request*>*naming* (in magenta) and *naming*>*request* (in cyan). Source strength was thresholded at 0.02 a.u.



Speech Act	x	y	z	Intensity [a.u.]	Hemisphere	BA areas	Cortical areas
Request	-26	-27	56	0.042	L	3/4	somatosensory/ motor cortex
	26	-27	58	0.088	R	3/4	somatosensory/ motor cortex
	-6	8	58	0.035	L	6	Premotor & SMA
	7	8	59	0.041	R	6	Premotor & SMA
	-53	-2	-27	0.271	L	20/21	Inferior temporal area
	53	-11	-27	0.161	R	20/21	Inferior temporal area
	-56	-26	35	0.046	L	48/2	Somatosensory/ Temporal lobe
	59	-25	35	0.047	R	48/2	Somatosensory/ Temporal lobe
Naming	7	9	64	0.11	L	6	Premotor & SMA
	-6	7	64	0.084	R	6	Premotor & SMA
	-60	-25	-12	0.068	L	20/21	Inferior temporal area
	60	-25	-14	0.076	R	20/21	Inferior temporal area
	-55	-25	36	0.070	L	48/2	Somatosensory/ Temporal lobe
	59	-25	36	0.070	R	48/2	Somatosensory/ Temporal lobe

Table 2.2: Source analysis results for the grand-averaged data of *naming* and *request* in the time window going from -600 ms to voice onset. For each condition, the table shows MNI coordinates, intensity, hemisphere, Brodmann labels and cortical areas.

2.3.3 Source analysis

To identify the cortical sources underlying the significantly different neurophysiological responses recorded prior to *naming* and *request* actions, we conducted a distributed source localization on those time windows where interactions between the factors Communicative act and Time window were significant (-600 to 0 msec relative to voice onset). Sources of the EEG responses for *naming* and *request* revealed activation of temporal-frontal regions (for more detail, see Table 2.2) with *request* function activating additionally bilateral motor cortex (BA3/4 with peak coordinates x=-26, y=-27, z=56 and x=26, y=-27 z=58, see Figure 2.3), which was not activated in *naming*. The proportion of unexplained variance was ca. 8% for both source estimates, which is comparable to that reported in previous studies and indicates successful source estimation (e.g., Miozzo et al., 2015). In addition, we computed the subtraction of the difference source maps of *request* > *naming* and of *naming* < *request* to further scrutinize the specific difference in cortical locus between these two speech acts. The results confirmed that *requests* produced stronger bilateral motor cortex activations as compared with *naming*. Conversely, mid-dorsal prefrontal and anterior-inferior temporal activation foci tended to be relatively stronger for *naming* (see Figure 2.3). Notice that no significant differences in source statistics were found, likely due to variability in single subject ERPs, and the source maps for the significant ERP time window was therefore computed to take advantage of the large signal-to-noise ratio of the grand average (see for instance Egorova et al., 2013; Hauk et al., 2006; Shtyrov, 2011).

2.3.4 Acoustic analysis

It is possible that neurophysiological differences relate to differences in the physical effort subjects spent during articulation. Although our EMG data speak against this possibility (see Figure 2.2, Panel B), it is important to also assess possible differences in the acoustic makeup of speech produced during *naming* and *requesting*. To this end, we performed an acoustic analysis of the produced utterances. Wilcoxon signed-rank tests were performed on the data, which did not show any significant differences in utterance duration (msec), loudness (RMS, dB), pitch (F0, Hz), jitter (ms), shimmer (dB) and harmonic-to-noise ratio (HRN, dB - see Figure 2.4 and Table 2.3).

Table 2.3: Values depict mean and standard error of the mean (SEM) of the acoustic proprieties of the utterances produced respectively as *naming* and *request* communicative acts. Z-values and p-values show the result of the Wilcoxon signed rank tests used to statistically compare the acoustic proprieties between Request and Naming conditions.

	Request		**Naming**			
	Mean	***SEM***	***Mean***	***SEM***	***Z-value***	***p***
Duration (ms)	621.458	25.002	608.439	24.428	0.941	0.346
Loudness (RMS, dB)	59.415	0.635	60.023	0.556	1.607	0.108
Pitch F0 (Hz)	173.298	11.097	170.269	11.018	1.445	0.149
Jitter (μs)	0.015	0.001	0.015	0.001	0.146	0.884
Shimmer (dB)	1.126	0.040	1.130	0.049	0.211	0.833
HNR (dB)	9.182	0.421	9.423	0.388	0.893	0.372

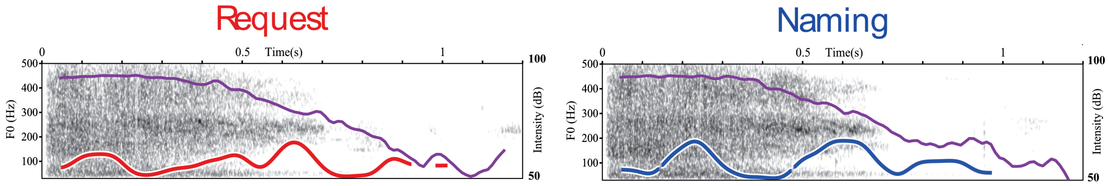


Figure 2.4: Acoustic proprieties for *naming* (right) and *request* (left): spectrogram plotted against time is illustrated in gray, the blue and red lines show the pitch (f0) contour and the purple line the loudness of speech over time.

2.4 Discussion

Before *naming* an object or *requesting* it from a partner, neurophysiological activations indicate the speaker's communicative intention, that is, the communicative function of the intended speech act. Specifically, a negative-going anticipatory potential resembling the readiness potential (RP) preceding the onset of motor acts appeared already ca. -600 msec before voice onset and, interestingly, distinguished between speech acts. Because the RP predicts upcoming movements and their muscular origin, whereas the anticipatory wave reported here indicates linguistic-communicative function, we prefer a different name for it and follow Grisoni (Grisoni, Moseley, et al., 2019) in calling it "prediction potential" and, to be more specific to the present context, "pragmatic prediction potential" (PPP).

PPP amplitudes were larger when the same verbal materials were used in interactions with a partner for *requesting* objects in a role play of shopping than when they were uttered for *naming* objects in a role play of language testing. Calculation of cortical currents underlying the predictive pragmatic potential before *naming*/*requesting* suggested differences between the underlying source constellations. In the motor system, more precisely in the motor cortex controlling the hand, there were stronger sources prior to *requesting* than *naming*. Even though we need to interpret the sources computed from grand-averages cautiously, one may consider that this results is compatible with the proposition that the brain correlates of *request* production reflect aspects of pragmatic information relevant for this speech act type. Speech acts are characterized by the set of partner actions they regularly entail, and for *requesting* physical objects, one of these typical partner reactions is the handing over of the *requested* item. It is possible that the motor system activation in anticipation of *request* production might reflect the prediction immanent to *requests* that the partner will perform the hand motor movement to follow the *request*. This interpretation draws on the idea that motor system activity can indicate actions of a partner, a finding well established by the body of research on Mirror Neurons (e.g., Rizzolatti et al., 2014; Rizzolatti & Craighero, 2004). Importantly, the additional motor system activation to *requests* as compared with *naming* was frequently reported in previous studies of speech act understanding using spoken, written and gestural utterances (see Section 2.4.1).

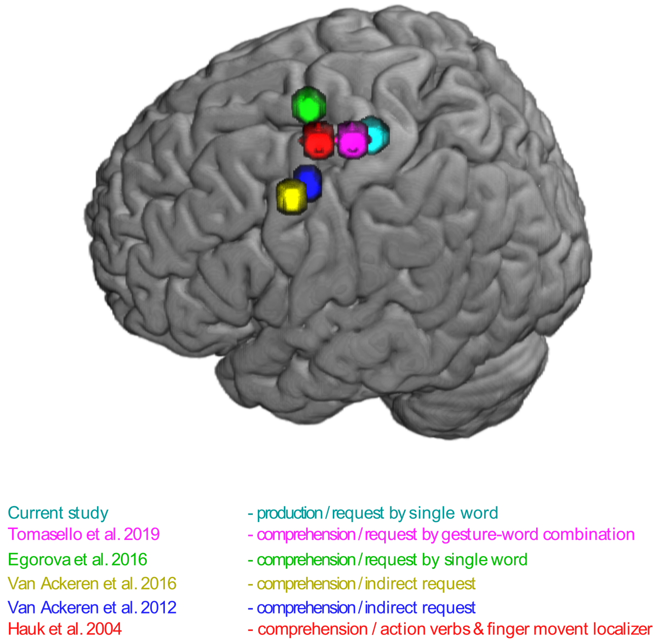
2.4.1 Brain activity anticipating upcoming speech act production

It is important to point out that previous studies have already investigated the neural basis of communicative function processing. These studies had participants observe or listen to recorded social interactions in/from a third-person perspective (computer-based experiments) (Bašnáková et al., 2015; Bašnáková et al., 2014; Egorova et al., 2014; Egorova et al., 2013, 2016; van Ackeren et al., 2012; van Ackeren et al., 2016). One very recent study used a second person perspective by presenting word-gesture combinations directly addressing the experimental subject, who occasionally had to respond to the perceived communicative acts by pointing to or handing over an object (Tomasello et al., 2019). Here, we complemented this previous research by looking at the first-person perspective, the case where the experimental subject herself performs the critical speech act in the context of language games, that is, simulated social interactions with a real confederate. Pragmatics, as the study of language in use in social context, requires such and related attempts to place language in communicative interaction contexts. Our study is thus in the spirit of recent developments in cognitive neuroscience, examining neural underpinnings of cognitive processes in general (Czeszumski et al., 2020; Hasson et al., 2012; Kasai et al., 2015) and to linguistic processes more specifically (Goregliad Fjaellingsdal et al., 2020; Hasson et al., 2012; Kuhlen et al., 2015) in more naturalistic and social settings.

In the present experiment, we show that the readiness like anticipatory brain activity called "prediction potential", which indicates semantic expectancy (for a review, see Pulvermüller & Grisoni, 2020), can also be an index of linguistic pragmatic information about upcoming communicative actions. Information about the speech act function of utterances was manifest 600 msec before voice onset. Previous studies reported similar anticipatory brain activity prior to perceiving predictable action sounds (Grisoni et al., 2016), specific actions and visually related written or spoken words (Grisoni et al., 2017; Grisoni, Mohr, et al., 2019; Grisoni et al., 2021), and predictable words in sentence context generally (León-Cabrera et al., 2019; León-Cabrera et al., 2017). Several of these studies also reported that differences in meaning between the predictable words were reflected in the topographies of the PP, thus providing a neural estimate of semantic prediction. A relevant critical question is to what extent the PPP found in the present study relates to the one found during semantic expectation in work on language comprehension (Grisoni et al., 2017; Grisoni, Moseley, et al., 2019). Although the two components, the semantic and the pragmatic PP, emerged in different modalities (comprehension and production) and in one case reflected a difference in meaning of the predicted target words and in the other one in speech act function, they are similar in at least four ways. First, they appear before a predictable meaningful symbol-in-context (word in semantic or speech act context). Second, they emerge slowly with a negative-going polarity and a maximum at fronto-central recording sites. Third, their sources are in part in motor systems, and fourth, unlike the RP, which indexes basic motor movement, they reflect higher cognitive information about action related meaning aspects or predictable partner actions at abstract semantic-pragmatic levels. Importantly, as reported in the present study, these prediction potentials are modulated depending on the linguistic semantic or pragmatic information attached to the upcoming utterances, i.e., their meaning and communicative function. Thus, it appears that there is a new family of brain responses, superficially similar to the RP, but with much broader and more far-reaching cognitive scope, which may be of relevance for future investigations into the brain's prediction mechanisms (Pulvermüller & Grisoni, 2020).

To further examine the consistency of the findings across neuropragmatic studies, Figure 2.5 presents results of previous experiments revealing brain indexes of speech act function. When calculating the distributed cortical sources of the PPP obtained in the present study for *naming* and *request* contexts (see Figure 2.3), bilateral precentral cortex activity tended to be stronger in preparation of *request* production compared with activity emerging before *naming* actions. This was confirmed also when calculating the differences source maps between *request* and *naming* functions

Figure 2.5: Motor cortex activation during *request* production and comprehension and during understanding of single action words. 6 mm spheres centered on the peak activation coordinates of *request* speech acts reported in the current production study (shown in cyan) and in previous speech act comprehension studies (other colors). For comparison, peak activation coordinates are also given (in red) for the overlap activation between action verb comprehension and finger motor localizer tasks (Hauk et al., 2004). Only peaks in the left motor cortex system are reported.



(i.e., *request*>*naming* and *naming*>*request*, see box in Figure 2.3). The peak voxel of the left precentral motor focus for *requests* had the MNI coordinates x=-26, y=-27, z=56, which was only 11 mm away from the one found in the recent neuropragmatic study by Tomasello et al. (2019) investigating comprehension of *requests* compared to *naming* in second person perspective (x=-28, y=-38, z=58). As shown in Figure 2.5, also the study by Egorova et al. (2016), which addressed speech act comprehension in third person perspective, and work on indirect *requests* by van Ackeren et al. (2012), van Ackeren et al. (2016) yielded comparable precentral activations. In spite of the degree of uncertainty immanent to neurophysiological source localisation (Hämäläinen & Ilmoniemi, 1984; Ilmoniemi, 1993), these neuropragmatic activation foci are localised close to each other and also close to an index of semantic processing of hand-related action verbs and finger movement reported by Hauk et al. (2004). This convergence of neuropragmatic results on preexisting speech act differences and semantic brain indexes indicates that close-by, overlapping or shared neuronal sources underlie the processing of *requests* in anticipation of speech act production and in speech act comprehension. This finding is consistent with, and therefore provides support for, neurocognitive psychological and linguistic theories claiming shared neuronal mechanisms being engaged in comprehending and producing social communicative actions (Pickering & Garrod, 2004, 2013; Pulvermüller, 1999, 2018; Strijkers & Costa, 2016). These results are not easily accounted for by brain language models that postulate a separation between the brain mechanisms of speech production and comprehension or by models not acknowledging a role of the motor system in semantic-pragmatic understanding and production. The evidence for a role of motor activity in indexing the pragmatic function of language sits nicely with a broad range of recent studies supporting the relevance of motor areas for the processing of other types of linguistic information, in particular at semantic (Dreyer et al., 2015; Dreyer et al., 2020; Grisoni et al., 2016; Hauk et al., 2004; Pecher et al., 2004; Pulvermüller et al., 2005; Shtyrov et al., 2014; Tomasello et al., 2017, 2018; Vukovic & Shtyrov, 2014) and phonological levels (D'Ausilio et al., 2009; Pulvermüller & Shtyrov, 2006; Schomers et al., 2015; Schomers & Pulvermüller, 2016; Strijkers et al., 2017).

2.4.2 Methodological considerations

In contrast to much work in speech production focusing on object *naming* in computer-controlled experiments, we here set out to move towards a novel paradigm that closely approximates real life social communicative interaction. It is clear that such an endeavor cannot result in real communication but can only approximate this goal to a degree, as it is necessary to control aspects of the experiment so as to allow for conclusions on the critical variable, that is, on speech act function in the present case. However, it is also clear that real life-approximating settings are in greater danger than standard ones of being confounded by factors not well controlled for. We gave our best to exclude some putative confounding factors and will summarize these below.

Crucially, the differences in neural response between communicative actions prior to speech cannot be attributed to the verbal and object material used, because across-subjects the same materials were used in preparation of, and to perform *naming* and *request* functions. In addition, different in neural responses cannot be due to mere anticipation of the motor response produced by the communicating partner, as this response was very closely matched between both communicative actions. To this end, we avoided differences in the subject's own actions following the critical (*naming/request*) speech act. In particular, subjects were not expected to perform hand actions during the experiment or respond otherwise to the confederate's activities. The only difference between conditions was the location where the object was placed: during *requests*, the object was placed in the "subject's basket", whereas in the *naming* condition, the object was removed from the table and placed in a "non-specified basket", a minor difference which is unlikely to explain the profound neurophysiological differences as we believe. We performed a further analysis to explore if the side of the confederate's response actions might have caused differences in the topographies of brain responses. This analysis did not show significant statistical differences, thus indicating that the predictive brain responses did to some degree abstract away from the actual subsequent partner actions, as they did not encode information about which hand (left or right) was used by the confederate to respond to the object *request*.

Despite the fact that the same single words were uttered in both speech act conditions under investigation, certain physical, acoustic and articulatory aspects of the produced utterances might have systematically differed between them. As the RP associated with overt body movements is known to vary in amplitude in a way that matches the physical properties of the prepared movement (Shibasaki & Hallett, 2006), differences in PPP between *naming* and *request* might have reflected subtle differences in the activity of the articulatory system, subsequently reflected by the acoustic properties of the produced utterances. To explore this possibility, we performed an acoustic analysis of the produced utterances. Convergingly, none of the examined acoustic measures (parameters) - which included duration, loudness, pitch, jitter, shimmer and harmonics-to-noise ratio (HNR) - differed significantly between conditions (see Figure 2.4 and Table 2.3). These results argue against a possible confounding by acoustic features of the produced utterances, although we cannot exclude with certainty that the utterances might have varied in ways that were not captured by the parameters observed here. The absence of any differences in acoustic properties of *naming* and *request* communicative actions produced in the current experiment appears to be in contrast with other findings by Hellbernd and Sammler (2016), who demonstrated that acoustic profile of same utterances produced with different communicative intentions differed and can also be reliably used by the listener to infer the latter. In particular, it is well-know from the linguistic literature that many speech act types differ in prosodic features. For instance, questions and statements expressed by the same sentence form have markedly different prosody in many languages, including, for example, English (Horn & Ward, 2005; Srinivasan & Massaro, 2003) and German (Schneider et al., 2012). For single word utterances as the ones used here, however, we are not aware of any studies showing consistent prosodic differences between *requesting* and *naming* actions. Therefore, the absence of acoustic or prosodic differences suggested by our analyses should not be taken as evidence against different communicative roles of the utterances used in the *naming* and *request* contexts of our study. Furthermore, the fact that specific acoustic profiles may help to convey speech act type to the listener does not mean that this type of information is necessary for the listener's correct understanding, or for the speaker's appropriate production. Instead, other types of information - such as many aspects of context, including action sequence and common ground - are available and disambiguate communicative function. In the present experiment, the lack of difference between acoustic profiles of *naming* and *request* functions could have been a consequence of the block design applied, in which the imaginary context was kept constant across trials so that subjects might have de-emphasized prosodic cues for indicating speech act function to the confederate. We also wish to stress that the neurophysiological and source responses documented by previous studies on communicative action processing used written words on a screen lacking prosodic information (Egorova et al., 2013; Tomasello et al., 2019) and showed results analogous to those revealed by the present study. This demonstrates that the neural activations patterns revealed here also appear in case prosody does not play a role in conveying communicative intentions.

For the same reasons elaborated above for prosody, we consider it improbable that different neural responses seen between *naming* and *request* were caused by differences in articulatory movements. As previous studies have shown a time delay of 100-200 msec between articulatory movement and voice onset (see Fargier et al., 2018; Salmelin, 2010), we repeated the cluster-based permutation tests in a reduced time window excluding these very last 200 msec preceding voice onset (where articulatory confounds appear likely), which revealed similar significant differences between *naming* and *request* as found across the entire time window. It should also be noted again that the computed EMG activity indicated equal articulatory contributions in both conditions across the entire time window of interest (see Figure 2.2, Panel B), which further argues against the possibility that differences in articulatory artefact underlie the differences identified in the EEG signals.

As a further possible caveat, due to embedding in a language game context approximating everyday communication, certain body movements, and in particular ocular movements could not be avoided entirely. As we anticipated this issue, our subjects were instructed to fixate a dot located in the center of the table before and while producing utterances, with the goal to reduce ocular activity. Also, analysis of the vertical and horizontal EOG signals in the same time window of interest used for EEG data analysis did not reveal any significant differences between the two conditions.

However, we cannot completely exclude the possibility that object preference had other effects. For example slightly different object selections might have been made in *naming* and *request* contexts. We did not take note of the exact object choices made from trial to trial, but should remind the reader that the picture set of objects was predefined for each block and exactly counterbalanced and matched across conditions, so that only the last picture remaining on the table at the end of a block might have systematically differed between *naming* and *requesting*, a difference unlikely to affect brain responses recorded across a large stimulus set.

For the reasons summarized above, we consider it as unlikely that the presence of articulatory or ocular artefacts or a selection preferences might have produced differences between the experimental conditions which acted as confounds of the results reported. But again, also in this case, there is no ultimate certainty; it is still possible that artefact-induced variability in the EEG and EMG signal might have made subtle differences between conditions (e.g., topographical differences) more difficult to detect statistically. Altogether, the larger pragmatic predictive potential (PPP) prior to *requesting* as compared to *naming* cannot be related to differences in the linguistic properties of the verbal material applied and are unlikely to be due to the way these were articulated or to their acoustic features. They can only be related to the distinct linguistic-pragmatic information intrinsic to the communicative context, in which critical words were articulated. Therefore, our study shows that, apart from any general RP-like function in indexing motor preparation, the PPP preceding speech acts reveals and predicts cognitive features of the upcoming speech acts, and in particular aspects of their illocutionary force.

2.4.3 Limitations and outlook

Here, we will take a closer look at the limitations of the present work and issues still left open for future study. Whereas differences in the size of predictive potentials could solidly be documented, our source localization showed different patterns of activated cortical areas in anticipation of *naming* and *requests*. However, these source estimations were based on grand-average event-related potential data. As already mentioned, data obtained from single subjects were too noisy and thus variable to allow for meaningful statistical analysis across conditions. Still, grand average potentials led to different activation landscapes, which we here interpret. We tried our best to avoid and reduce noise in the electrocortical responses (ICA analysis, interpolation of bad electrodes, rejection of data from 3 subjects due to bad data). However, the only way for obtaining source estimates with good signal-to-noise ratios was to calculate them from grand average data. This limits the conclusions from the source estimates, as no statistics on the obtained sources was possible. Even if the precentral activation focus seen in *request* preparation but not in the *naming* context fits very well with previous neuropragmatic studies (see Fig. 4), and even though it emerged in the source map of *requests* and again in the brain map sources of *request>naming*), it is necessary to reconfirm this result by future studies applying source statistics and, crucially, direct statistical comparisons between conditions. However, the noisiness of neurophysiological recordings before and during speech production appears as a major obstacle here.

We found a difference in brain indicators of speech act processing consistent with the idea that the predictable partner actions are to a degree reflected in the brain response characterizing a speech act. However, it is important to note that such a difference in the sequence structure of speech acts is only one of the many aspects that may be relevant, and that may in principle be reflected at the level of the brain. In fact, *request* actions differ from *naming* not only in terms of their sequence structure (i.e., typical follower actions), but also in terms of attention (directed to the object in the case of *naming* and to both object and to the partner in the case of *request*), memory (later checking whether the right object has been selected by the confederate), and degree of complexity of the social situation (lower for *naming*, higher for *requests*). Furthermore, *requests* and *naming* actions, even if both performed in a communicative setting such as shopping and examination, differ with regard to motivational, affective and emotional factors and in mental states including theory of mind. Please think of the desire of the *requesting* party characterizing a true *request* or the belief of the examinee that the tester knows the correct answer in the test. One may argue that such affective-emotional-mental differences confound our study and make it impossible to attribute the results to speech act function. However, we have to strongly argue against such a position. In fact, all of these above-mentioned differences are intrinsic to the speech act types targeted, and each of them may be relevant for the neurocognitive differences observable in the current paradigm and in similar neuropragmatic studies. Speech acts come as a package of knowledge, beliefs, intentions, emotional states and also utterances to be produced, and it is a relevant topic of current research to examine any differences in brain indexes between them. In addition, other aspects of the actions predictably following the to-be-performed speech acts might become manifest in brain activity. To disentangle which aspects of the investigated speech acts is critical for the observed neurophysiological differences remains to be matter for the future. At present, we can only offer hypothesis about which specific factor(s) was reflected.

Disentangling some aspects of the investigated speech acts and their specific brain indexes may be possible in the comparison between similar studies. In Egorova and colleague's fMRI study, there was a range of brain areas that became more strongly active in *request* as compared with *naming* contexts (Egorova et al., 2016). Over and above premotor cortex, these areas included temporo-occipital cortex, which may point to a difference in specific attentional loads. A possible reason why these latter neural differences were not replicated in the present study could relate to the matching for general communicative embedding between the conditions of the present experimental design. The parallel instructions motivating subjects to imagine real life interactions (between a salesman and a customer and between an examiner and a testee) may have contributed to similar focused visual attention being directed toward objects and therefore may have cancelled any differences in posterior temporal-occipital cortical activation. Needless to say, this is hypothetical and requires future follow up by controlled experiments. Although we have highlighted the possible role of the premotor activation enhancement during *requests* as a brain index of action sequence structure processing, we do not wish to exclude the relevance of other features that distinguish speech acts at the cognitive and neural levels. Hence, further studies with more precise localization tools should investigate more closely the specific cortical locus of subtypes of speech acts in social interaction.

A further clear limitation of our work relates to the role play settings implemented. As the simulated shopping and test scenarios had the character of role plays, they were markedly different from actions in real communicative situations. Thus, one may argue that the subjects may just not have followed the instruction and refrained from joining the game. In this case, some type of *naming* would have been performed in both conditions and the neurophysiological differences, which in part match previous results, would be unexplained; therefore, we consider this possibility as not so plausible. Additionally, the lack of main effect of Exposure time or interaction between the factors Communicative act and Exposure time (first vs second experimental block), fails to support any general or differential fatigue or disengagement effects in *request* and *naming* conditions. However, it may still be that aspects of the brain responses reflect the artefactual role play scenarios and may not be generally present during speech act processing in real life conditions. Further-more, because of the block design, the type of speech act performed by the subject as well as the response produced by the confederate was constant across several trials. This rigidity in the dynamics of the dialogues, along with their elementary character (including only the target speech act and its most likely successor), does not fully reflect natural communication, where each speaker's contribution can only be predicted probabilistically and may vary across multiple plausible options (see Gisladottir et al., 2018) while unexpected response actions cannot be excluded. Therefore, future work towards more natural communicative settings should attempt to integrate event-related designs, where speech act type is randomized across trials (e.g., as in Tomasello et al., 2019), as well as a diversification of the response of the interlocutor (e.g., as in Egorova et al., 2014). There is good reason to strive for even more close approximation of real-life situations, although there are certainly limits to this endeavor due to the need for controlled experimenting.

One more fruitful direction of future study is the investigation of directive speech acts of different types, including *requests* that do not refer to concrete objects. In the current study, *requests* were operationalized as asking for an object with the intention to have the listener hand it over. However, although this type of *request* is extremely common in everyday situations, it does not exhaust the different types of *requests* and directive speech acts. In fact, one might as well *request* things that are non-material (e.g., *request* some money to be transferred electronically to a bank account), or abstract (e.g., *request* attention, *request* more time for completing a task). Likewise, speech acts such as *requesting*, *commanding* and *asking questions*, which all are grouped together in Searle's category of "directive speech acts" (Searle, 1979) may be characterized by shared and distinctive neurocognitive features, thus providing much motivation for additional study. One might hypothesize that subtypes of *requests* and directives share their neural signatures with those found here for object-related *requests* in the current study. The question of whether this is really the case is however still open.

From a theoretical perspective, the current experiment contributes to the body of literature exploring the mechanisms of speech production. However, because of the characteristics of the slowly rising predictive potential and because of the absence of additional experimental factors, this study cannot relate processing of speech act type to other aspects of linguistic processing such as semantics or phonology, and in particular it cannot establish the temporal relationship between them. Note that present work on speech production suggested near simultaneous access to semantic, lexical and phonological information during speech production in the standard *naming* paradigm (Miozzo et al., 2015; Strijkers et al., 2017). The time course of pragmatic information access in speech production still needs to be investigated in such contexts, similar to earlier work in the domain of language comprehension (for example, see Egorova et al., 2013; Tomasello et al., 2019).

In summary, this study on brain signatures of speech act production revealed (i) a predictive index of speech act function starting ca. 600 msec before the actual articulation begins. Our study also provided strong evidence that (ii) different predictive brain indexes appear for different speech act functions, in our present case *naming* and *requesting* performed using identical linguistic forms. Finally, (iii) the estimated cortical sources differentiating between prediction potentials of *naming* and *requesting* resembled those found earlier during communicative function understanding. Even though some of these conclusions call for confirmation, as pointed out above, these results provide support for the claim that (not only linguistic form but, in addition) speech act function is neurally manifest in specific definable cortical activation patterns and that cortical-mechanistic resources are (at least partly) shared between speech act production and comprehension.

2.4.4 Conclusion

The current study investigates neural activity prior to speech production, when subjects use the same words to do different things, to perform speech acts with different functions. In one case, subjects were *naming* objects, while in the other case they were *requesting* them. We found larger predictive brain potentials when subjects were preparing for a *request* as opposed to object *naming*. Also, the brain activity patterns underlying the predictive potential differed insofar as significant sources in the hand motor cortex could only be found prior to *requests* but not in preparation of *naming* actions. In contrast to the readiness potential, which indicates motor preparation, we conclude that the predictive potential reported here reflects linguistic-pragmatic information about specific action-related communicative functions. On the background of earlier neuropragmatic work (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2019), our present results indicate that shared neuronal mechanisms contribute to the planning and production and to the perception and understanding of speech acts.

Chapter 3

Does the right temporo-parietal junction play a role in processing indirect speech acts? A transcranial magnetic stimulation study

Abstract

In communication, much information is conveyed not explicitly but rather covertly, based on shared assumptions and common knowledge. For instance, when asked “Did you bring your cat to the vet?” a person could reply “It got hurt jumping down the table”, thereby implicating that, indeed, the cat was brought to the vet. The assumption that getting hurt jumping down a table motivates a vet visit is tacitly attributed to the speaker by the listener, which might engage Theory of Mind (ToM) processes. In the present study, we apply repetitive transcranial magnetic stimulation to the right temporo-parietal junction, a key brain region underlying ToM, with the aim to disrupt ToM processes necessary for language understanding. We then assess the effects on the comprehension of indirect speech acts and their matched direct controls. In one set of conditions, the direct and indirect stimuli were not matched for speech act type, whereas, in the other, they were matched, thus providing an unconfounded test case of in/directness. After rTMS to the right temporo-parietal junction, in a pragmatic judgment task, responses to indirect speech acts were delayed relative to direct ones (when both were meant to be a *statement* about a given state of affairs). However, there was no such TMS-related reaction time difference between direct and indirect speech acts when they were not speech act matched, with the indirect ones conveying the *rejection* or *acceptance* of an offer. Therefore, we do not find evidence that the rTPJ is causally involved in comprehending indirectness *per se*, but conclude that it could be involved instead in the processing of specific social communicative action of *rejecting* or *accepting* offers, or to a combination of differing in/directness and communicative function. Our findings are consistent with the view that ToM processing in rTPJ is more important and/or more pronounced for offer *acceptance/rejection* than for true question *answering.*

3.1 Introduction

3.1.1 Linguistic indirectness

Linguistic indirectness is a common phenomenon in human communication. When a person asks “Did you bring your cat to the vet?” and the hearer replies “It got hurt jumping down the table.” it is usually clear that the hearer is thereby confirming that he/she is bringing the cat to the veterinary, in spite of the absence of an explicit statement to this end. This reply is an example of an indirect speech act, because the speaker *“utters a sentence, means what he says, but also means something more”* (Searle, 1979). According to Grice, indirect speech acts can be understood by the hearer because they assume that the so-called Maxim of Relevance is obeyed, that is, that the speaker says something of relevance for the current scopes of the ongoing conversational exchange (Grice, 1975). This linguistic phenomenon is therefore also known as a Relevance implicature. According to the Gricean and Searlean framework, it is then up to the speaker, to deploy a chain of inferences allowing them to identify the intended communicated message. This inferential chain can be worked out thanks to the assumption of relevance combined with other world knowledge and contextual information. In particular, Theory of Mind (ToM), the capacity to ascribe mental states and processes to others, has been thought to play a central role in comprehension of indirectness, above and beyond what is usually involved in any communicative situation. Namely, it has been thought to contribute to understanding the communicative intention conveyed indirectly by the speaker.

3.1.2 Indirect speech acts and speech act type

The question of the neurocognitive mechanisms of comprehension of indirect speech acts has motivated ample research. Investigating indirectness involves comparing utterances that are used to carry out indirect speech acts to utterances used to carry out direct ones. This strategy however also comes with a risk. Sentences used in direct and indirect speech act conditions differ in structural dimensions such as lexical, morphological or syntactic ones. One solution to avoid these putative problems is to employ identical sentences and utterances for direct and indirect speech act conditions, which may minimize the likelihood of these confounds. This approach has been largely adopted in the last years. For instance, van Ackeren et al. (2012) used exactly the same utterance “It is hot here” in direct and indirect speech act conditions. In the context of a desert landscape, the utterance was only used to describe the temperature in the desert. However, in the context of the picture of a room with a closed window, it could be understood as carrying out an indirect speech act, specifically an indirect request. While using this approach successfully achieves a structural comparability between the direct and indirect stimuli, it does not achieve functional comparability. Indeed, note that the two experimental conditions differed not only in their indirectness, but also in the type of speech act that they carried out (*statement* vs. *request*). Therefore, the necessary precaution of using identical sentences does not guarantee successful matching of direct and indirect speech act conditions. Any difference in behavior or brain activity between the conditions of van Ackeren et al. (2012) could thus be a result of their difference in in/directness, of that in speech act type, or both. The communicative function of the speech act needs to be taken into account and excluded as a possible confound when investigating this phenomenon. We note however that – to the best of our knowledge - all previous studies of indirect speech acts were subject to this or the previous confounds regarding utterance form and/or speech act function.

This consideration is of relevance as different (direct) speech acts (SAs) have been found to be associated with varying patterns of activations in the brain. For instance, a range of neuroscientific methods, including EEG, fMRI and MEG allowed to compare *request* to *naming* SAs. It was shown that comprehending or producing *requests* conveyed by same utterances is associated with greater activations of the motor system (Boux et al., 2021; Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2019) and also of ToM regions such as the rTPJ along with Broca's area and bilateral parietal and temporo-occipital areas (Egorova et al., 2013, 2016) compared to comprehension of the same utterances used to perform a *naming* speech act. Interestingly, when *requests* are performed indirectly (e.g., "It is warm in here" as an indirect request to open the window), they are also associated with BOLD activations in the action system (van Ackeren et al., 2012; van Ackeren et al., 2016), similar to direct requests. It therefore appears that brain signatures specific to certain speech act classes might be present also when these are performed indirectly. In other words, it is possible that additional cognitive mechanisms are required for the listener to process the speech act type performed indirectly, when contrasted with the same utterance performing a different speech act directly.

3.1.3 Processing of indirect speech acts

Examining the literature shows that the typical approach used so far – both in behavioral and neuroscientific studies - has been to contrast a given utterance used to perform a certain type of direct speech act with the same utterance used to perform a different indirect speech act. Such a contrast however may, together with indirectness, also capture neurocognitive signatures of speech act type processing that are not inherent to indirectness processing *per se.*

First, behavioral studies consistently reported that indirect speech acts take longer to be understood than direct ones (Jang et al., 2013; Shibata et al., 2011). Importantly, this difference persists also when direct and indirect speech acts performed by the means of the same utterance are compared (Feng et al., 2017; Feng et al., 2021; Hamblin & Gibbs, 2003; Holtgraves, 1999). These results indicate that additional processing costs are required to understand a given utterance when it is intended as an indirect rather than as a direct speech act. These processing delays are often attributed to the process of inference that - in the Searle-Grice perspective - the receiver must engage in to understand the indirectly conveyed message. The Searlean process of comprehending indirect speech acts is based on a multi-step process involving, among others, understanding the direct meaning of the utterance, detecting that the speaker is deviating from general cooperative principles of conversation, identifying that the deviation is intentional and then using general world knowledge that is part of the common ground as well as deductive reasoning to access the implicated meaning. While this multi-step procedure requiring explicit reasoning may appear not fully plausible (Gibbs, 2002; Searle, 1979), understanding of indirect speech acts might require an increased engagement of the cognitive function of Theory of Mind (ToM) processing to monitor the common ground including shared assumptions and intentions (Stalnaker, 2002). Although communication is likely to always require ToM processing, it appears plausible that indirect speech acts are more strongly dependent on it, as additional inferential processes may be engaged to determine the implicated propositional content and communicative function. Indeed, some studies find a link between comprehension of indirect requests and ToM in healthy adults (Trott & Bergen, 2018) and clinical populations (Champagne-Lavau & Joanette, 2009; Champagne-Lavau & Stip, 2010)). For instance, individual differences in ToM abilities predicted how likely subjects were to interpret a remark as an indirect *request* (Trott & Bergen, 2018). Similarly, it was found that the accuracy in a meta-linguistic indirect *request* comprehension task was predicted by ToM function in right hemisphere damaged patients (Champagne-Lavau & Joanette, 2009) and in schizophrenic patients (Champagne-Lavau & Stip, 2010). Importantly, however, altogether these behavioral studies did not report whether the speech act type carried out in the direct and indirect condition were matched (Feng et al., 2017; Feng et al., 2021; Hamblin & Gibbs, 2003; Holtgraves, 1999) or deliberately compared direct non-directive speech acts to indirect directives (Champagne-Lavau & Joanette, 2009; Champagne-Lavau & Stip, 2010), thus either showing that, or leaving it open whether, the confound related to speech act type applied.

From a neural perspective, ToM function has been known to be consistently associated with a set of brain areas including the temporo-parietal junction (TPJ), the medial prefrontal cortex (mPFC), the precuneus (PreCun) and – albeit less consistently - the temporal poles (TP) and the posterior superior temporal sulci (pSTS) (Schurz et al., 2013; Schurz et al., 2014; Schurz et al., 2021; Van Overwalle & Baetens, 2009). Functional magnetic resonance (fMRI) studies have assessed which neural networks are active during comprehension of indirectness in healthy neurotypical adults. These, have consistently found the ToM brain network – particularly the rTPJ and in the mPFC - to be more strongly activated for indirect replies vs. direct replies (Jang et al., 2013; Shibata et al., 2011), also when these where conveyed by the same utterance (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; van Ackeren et al., 2016). Here, again, however, it was not the case, or was not clear whether indirect speech acts were compared to direct ones conveying same communicative function. For instance, a recent study addressed the speech act type confound by comparing direct with indirect requests and, in addition, with non-directive indirect 'replies' conveyed by the same utterance. For example, the sentence "It is quite far away" was used as a statement directly answering a question ("How far away is China?"), as a request indirectly responding to an offer ("Shall I move the TV closer?") and, as the newly added control condition, an indirect answer to a question ("Have you started preparing for the exam?"). However, also in this case, it is not clear the 'indirect answer' differs from the direct one not only in directness but also in speech act function as they do not report on matching them. Indeed, the reported example stimuli show that the indirect one functions, in addition, as an *excuse*. These authors claimed that the ToM network activation patterns (note that only the left hemisphere as analysed) observed during comprehension of indirect requests are to be attributed to indirectness rather than to the fact that a request is being expressed (van Ackeren et al., 2012; van Ackeren et al., 2016). This however omits the possible role of the different illocutionary roles of their direct and indirect replies. Therefore, overall, neuroimaging studies investigating the neural signatures of indirectness do consistently find associations between stronger activations in the ToM system and comprehension of indirectness. However, the interpretability of these neuroimaging results in unclear too, given that the confound of speech act type was not sufficiently controlled for.

Additionally, neuroimaging studies only allow for identifying correlations between a given cognitive process and activations in specific brain areas. Only one study attempted to address the issue of causality of the ToM-supporting rTPJ region in processing indirectness (Feng et al., 2021). They directed transcranial direct current stimulation (tDCS) to the right temporo-parietal junction (rTPJ), which, as mentioned above, is important for ToM processing (Saxe & Wexler, 2005; Schurz et al., 2014), and observed alterations in the performance in an indirect SA comprehension task and in a ToM task. An additional analysis indicated that the alterations in the comprehension of indirect speech acts were mediated by ToM function. However, once again, not report of speech act matching was provided.

So, overall previous studies on indirectness did not isolate the phenomenon of indirectness form other factors, in particular an additional, potentially confounding difference in SA function (i.e., illocutionary role/force), as they did not choose stimuli in which the same utterances were used to perform the same type of speech act both in the direct and indirect conditions. Additionally, among the indirect speech acts, a predominance of speech acts known to be associated with ToM (e.g., *requests*) or likely to be so (e.g., *excuses*, *promises*, *negative opinions*, etc.) can be noticed. It therefore cannot be excluded that the increased ToM activations found for comprehension of indirectness were in fact due to processing these specific types of speech acts rather than indirectness *per se.* On the background of this body of research, it is necessary to re-evaluate the evidence on indirectness of speech acts with different communicative functions in order to find out whether previous findings were due to indirectness or rather to any differences in the communicative function (speech act type) of the investigated utterances.

3.1.4 Experimental design and predictions

The question of whether rTPJ is causally involved in processing indirect speech acts is therefore still unanswered. Here we report the first study comparing direct and indirect speech acts that were performed with identical utterances and were matched as closely as possible for their illocutionary role or communicative function. In addition, a second set of stimuli was used, where direct and indirect speech acts were performed with the same utterance but had different speech act functions, similar to the approach used in previous research. Subjects were exposed to repetitive TMS stimulation to the right TPJ in one session, and to sham stimulation in another session. After verum or sham TMS, subjects underwent a Pragmatic Task, where they were shown replies that could be understood as direct or indirect depending on the preceding question. Subjects had to evaluate whether the reply could be interpreted as a "yes" or "no" and indicate this by button presses. Response times were measured and evaluated against the following predictions: (i) Response times are longer for indirect than for direct speech acts. (ii). TMS to the rTPJ alters reaction time differences between direct and indirect speech acts. A set of alternative predictions postulated that processing differences between direct and indirect speech acts are reduced or absent for stimuli matched for communicative function type. In this case, predictions (i) and (ii) would hold for unmatched, i.e., speech-act confounded conditions, but no for matched ones. As the behavioral modulation after rTPJ stimulation is frequently attributed to a modulation of ToM processing, we also had our subjects perform a ToM task to ascertain that ToM processing was indeed affected by our procedures.

3.2 Material and methods

All tasks were programmed in Matlab 2012b (The MathWorks Inc., Natick, MA) in combination with the Psychtoolbox 3 toolbox. Statistical analysis was conducted with Python 3.6 and R (RC-Team, 2019).

3.2.1 Experimental subjects

28 subjects were tested for the present study. Subjects were admitted to the study if they (i) were aged between 18 at 35 years, (ii) were right-handed, (iii) did not wear any implant that was incompatible with TMS, (iv) were native speakers of English and grew up in a monolingual environment (v) had no neurological or psychological disorder and (vi) were not color-blind. The study was carried out in accordance with the Ethics Committee of the Charité Universitätsmedizin (Berlin, Germany), which approved all the study procedures. After subject exclusion (see section 2.6) our final sample size was of 27 subjects (14 females, 13 males), who had a mean age of 23.7 years ± 4.4 SD and a mean LQ of 80.5±24.1 SD based on the Edinburgh Handedness Test (Oldfield, 1971). All participants signed an informed consent form prior to the beginning of the experiment and received a monetary compensation.

3.2.2 Pragmatic task

The Pragmatic task was based on a subset of the stimuli nearly identical to those used by Boux et al. (2023) (see Table 3.1). It consisted of critical replies that were presented into two alternative contexts constituted by interrogative sentences. One context favored a direct reading of the critical reply (direct condition), while the other favored an indirect reading (indirect condition). Thus, the critical stimulus, namely the reply to the context sentence, was identical for direct and indirect condition. The context sentences were always polar questions, and the critical replies were thus always interpretable as conveying a “yes” or a “no”. Critical replies were always expected to be interpreted in the same way in both their contexts (e.g., always either as a “yes” or as a “no”). In addition, there were two conditions. In the Speech-Act-matched set (SA-matched), the context sentences both in the direct and indirect conditions were used to perform what Searle classifies as ‘true’ question querying information and the replies were providing that information. In the non-Speech-Act-matched (non-SA-matched) condition, the interrogative sentence constituting the direct context was still querying information, such that the direct reply would be providing this information. However, the same context sentence in the indirect

Table 3.1: Examples of direct and indirect speech acts in the SA-matched and non-SA-matched sets together with the expected correct interpretation. For each condition, the illocutionary roles of the interrogative sentence constituting the context (CONTEXT) and the critical reply utterance (CRITICAL REPLY) are given in columns headed CONTEXT SA and REPLY'S SA, respectively. The last column indicates the expected response to the question, namely whether the reply is meant as a "yes" or "no" to the context question.

SET	CONDITION	CONTEXT SENTENCE	CONTEXT SA	CRITICAL REPLY	REPLY'S SA	EXPECTED INTERPRETATION
SA-matched	direct	**Is your cat hurt?**	true question	**It got wounded.**	true answer	yes
	indirect	**Are you bringing your cat to the vet?**	true question		true answer	yes
	direct	**Does Megan eat meat?**	true question	**She is vegetarian.**	true answer	no
	indirect	**Is Megan coming to the steakhouse?**	true question		true answer	no
non-SA-matched	direct	**Are you eating something?**	true question	**I am having a soup.**	true answer	yes
	indirect	**Do you want a spoon?**	offer (or proposal)		accepting the offer	yes
	direct	**Have you decided on a destination?**	true question	**We are not sure where to go yet.**	true answer	no
	indirect	**Shall I buy the train tickets?**	offer (or proposal)		rejecting the offer	no

condition was an offer or proposal, so that the indirect reply was in fact the refusal or acceptance of the offer. The SA-matched set included 70 pairs of direct/indirect items, whereas the non-SA-matched set included 62. In each set, half of the pairs were to be interpreted as "yes" and half as "no". Our *a priori* classification of the direct and indirect replies as respectively entailing or implicating a "yes" or a "no" was validated and indirect replies were rated as significantly less direct than direct ones by an independent sample of 28 participants (Boux et al., 2023). Before the experiment, subjects were informed that they would be shown question-reply pairs, drawn from conversation between people where one person asks the question and the other replies. It was specified that the reply was a complete conversational turn (i.e., that the person replying was not adding further utterances after the reply itself). Subjects were instructed to indicate as quickly and accurately as possible by pressing a key with their right hand whether they interpreted the reply as a "yes" or "no".

To exclude potential context effects due to similarity between context questions and critical replies in the direct and indirect conditions, these conditions were matched for a set of psycholinguistic properties: length of the context question counted in words, pronoun repetitions between context sentence and critical reply, number of coreferences between the context sentence and the critical reply, number of repeated lemmas between context and critical reply and semantic similarity between context question and reply sentences. The latter was quantified as the cosine between their semantic vectors obtained based on Latent Semantic Analysis (LSA, Landauer et al., 1998; Landauer et al., 2007). The LSA analysis is a method that allows to generate multi-dimensional semantic spaces based on word co-occurrences within documents in a corpus. Individual words can then be represented in this semantic space as vectors. Even entire (novel) sentences can be represented as vectors resulting from the sum of the vectors of their individual word components. Therefore, the semantic distance between two sentences can be calculated as the cosine of the angle between two vectors. The cosine similarity between each question and its corresponding reply was obtained from the online tool, http://lsa.colorado.edu/, selecting the term-to-term comparison and applying it to the tasaALL semantic space (300 semantic dimensions). The corpus on which the semantic space was based included text from different sources such as novels, newspaper articles and other texts, which were estimated to correspond to the reading level up to a fist-year college student.

All above mentioned properties were matched between the eight conditions resulting from the crossing of the factors of SA-matching, reply's expected Interpretation and Pragmatics (see Table 3.2 and 3.3). Specifically, differences in cosine similarity and length of context question between conditions were not significant

Table 3.2: Psycholingustic properties of the stimulus material. The items are split by SA-matching (SA-matched, non-SA-matched), Interpretation (Yes, No) and In/Directness (Direct, Indirect). The number of items (n) is indicated for each condition. Note that SA-matched and non-SA-matched differ in their number of items. None of the measures revealed a significant difference between stimulus sets.

	SA-matched (n=70)		**non-SA-matched (n=62)**	
	Yes (n=35)	**No (n=35)**	**Yes (n=31)**	**No (n=31)**
Length critical utterance in words (mean ± SD)	5.46 ± 1.54	5.23 ± 1.21	5.90 ± 1.25	5.52 ± 1.46
Number of content words in critical utterance (mean ± SD)	2.77 ± 1,03	2.71 ± 0.62	2.81 ± 0.95	2.55 ± 0.85

as assessed by a 2x2x2 ANOVA with the factors In/Directness$_{[direct,indirect]}$, SA-matching$_{[SA-matched,non-SA-matched]}$ and Interpretation$_{[yes,no]}$ (all main and interaction effects had p>0.05, see Table 3.3). Number of repeated pronouns, number of coreferences and number of repeated lemmas were also comparable between conditions, as assessed by likelihood-ratio chi-squared tests applied to all (12) relevant pairwise comparisons (all p>0.05, see Table 3.3). Finally, we also tested differences in length of critical reply and in number of content words in the critical replies by the means of a 2x2 ANOVA with factors SA-matching$_{[SA-matched,non-SA-matched]}$ and Interpretation$_{[yes,no]}$. These were also not statistically significant (all main effects and interaction effects had p>0.05, see Table 3.2). All stimuli were divided in two matched lists, such that for each pair, the direct and indirect version of the stimulus were on separate lists. As each subject performed the task twice (once in the verum session and once in the sham session), one list was used for each session and the attribution of a list to the first or second experimental session was counterbalanced across subjects. Thus, the same critical reply was presented twice to each subject, but in separate sessions, and once in the direct condition and on the other occasion in the indirect condition.

The stimuli were presented as black text appearing in the center of the screen on a grey background. First the context sentence was presented remaining on screen for 2s, then disappeared and was followed by a fixation cross for 0.5s. Then the critical reply appeared and remained on screen for 3s during which the subject had to respond and response times were recorded. Finally, the critical reply disappeared and the trial was concluded with a fixation cross appearing for 2s, before the next trial started. Responses were given via a left or right arrow key press. The correspondence between key and interpretation was randomized across subjects but kept constant across sessions for participant. Each session thus contained 132 trials and lasted about 17 min.

Table 3.3: Psycholingustic properties defining the relationship between the critical replies and their context question. The items are split by SA-matching (SA-matched, non-SA-matched), Interpretation (Yes, No) and In/Directness (Direct, Indirect). The number of items (n) is indicated for each condition. Note that SA-matched and non-SA-matched differ in their number of items. None of the measures revealed a significant difference between stimulus sets.

	SA-matched (n=140)				**non-SA-matched (n=124)**			
	Yes (n=70)		**No (n=70)**		**Yes (n=62)**		**No (n=62)**	
	Direct (n=35)	**Indirect (n=35)**	**Direct (n=35)**	**Indirect (n=35)**	**Direct (n=31)**	**Indirect (n=31)**	**Direct (n=31)**	**Indirect (n=31)**
Cosine similarity (mean ± SD)	0.68 ± 0.13	0.65 ± 0.17	0.65 ± 0.15	0.65 ± 0.13	0.68 ± 0.11	0.65 ± 0.13	0.64 ± 0.12	0.62 ± 0.11
Length context question in words (mean ± SD)	5.66 ± 1.21	5.54 ± 1.36	6.06 ± 1.33	6.29 ± 1.27	5.97 ± 1.58	6.16 ± 1.16	6.06 ± 1.31	5.94 ± 1.29
Number of repeated pronouns (sum)	8	8	6	6	4	2	1	3
Number of coreferences (sum)	32	32	35	35	34	32	36	36
Number of repeated lemmas (sum)	9	12	11	8	8	7	7	8

3.2.3 Theory of Mind task

The Theory of Mind task was originally designed by Apperly et al. (2011). In the present design we used the improved version developed by Hartwright et al. (2012). The task measures two relevant aspects of Theory of Mind: processing of belief and processing of desire. Thus, experimental subjects needed to predict the behavior of a fictional character in the task based on the character's beliefs (true belief: B+, false belief: B-) about the location of a given food item and the character's desire (approach: D+, avoidance: D-) of that very same food item. The factors of Belief and Desire were orthogonal and therefore yielded four different conditions.

Each trial started by the presentation of three different types of statements: (i) state of affair statement, indicating whether a given food item was located in a red or in a blue box, (ii) belief statement, indicating whether the character believed that the food item is in the blue or red box and (iii) desire statement, indicating whether the character loved or hated the food item (see Table 3.4). These statements were presented sequentially in randomized order for 1.2s each and separated by a 0.4s blank screen. Subsequently, a fixation cross was displayed for 0.4s and, then followed by either one of two images presented for 1.7s and during which the experimental subjects were expected to produce a button press. In test trials (66.6% of trials), the image depicted the character sitting at a table with a blue and red box at each

Table 3.4: Examples of stimuli in the various conditions of the Theory of Mind Task.

CONDITION	STATE OF AFFAIR STATEMENT	BELIEF STATEMENT	DESIRE STATEMENT	CORRECT RESPONSE IN TEST TRIALS	CORRECT RESPONSE IN CATCH TRIALS
B+D+	Donuts are in the **red** box.	He thinks the donuts are in the **red** box.	He **likes** donuts.	red box	red box
B-D+	Donuts are in the **red** box.	He thinks the donuts are in the **blue** box.	He **likes** donuts.	blue box	red box
B+D-	Donuts are in the **red** box.	He thinks the donuts are in the **red** box.	He **hates** donuts.	blue box	red box
B-D-	Donuts are in the **red** box.	He thinks the donuts are in the **blue** box.	He **hates** donuts.	red box	red box

side. In such case, the subject was expected to indicate by button press which box the subject would open, based on his/her beliefs and desires. In catch trials (33.3% of trials), a similar image was presented, but the character was absent and replaced by a question mark signaling that the experimental subject had to indicate the real location of the food item. Finally, in both trial and catch trials, a fixation cross appeared for 3s until the next trial started. Overall the task had 96 trials per session and lasted about 15 min. Subjects were asked to read the statements carefully and, as soon as the image with the character appeared, they had to indicate a quickly and accurately as possible which box (left vs. right) the subject will open by pressing the corresponding key. Conversely, in the catch trials, they were instructed to indicate where the food item was actually located instead (irrespective of the character's belief and/or desires).

3.2.4 TMS stimulation

TMS was delivered using a MagPro X100 system (MagVenture, Farum, Denmark) coupled with a 70 mm figure-of-8 coil in the verum condition and with a sham coil in the sham condition. TMS was applied off-line to the rTPJ prior to the Pragmatic and Theory of Mind task and subjects were blind to the nature of the sham or verum stimulation. The stimulation protocol was taken from Young et al. (2010) and consisted of biphasic pulses at a frequency of 1Hz applied for 25 minutes with the handle of the coil pointing backwards. The only modification that we introduced was the use of the resting motor threshold (RMT) to define the intensity of the stimulation. In the context of RMT procedure, the motor-evoked potential (MEP) of the subjects induced by the TMS pulses directed to the right motor cortex were measured by electromyography of their Abductor pollicus brevis (APB) in a belly-tendon montage. The resting motor threshold was defined as the intensity which elicited an MEP response larger than 50 µV in 5 out of 10 pulses in the APB muscle (Rossini et al., 1994). The final stimulation intensity was set to 90% of the RMT, as it is common in TMS research (e.g., see Donaldson et al., 2015). In the few cases where the final stimulation intensity provoked muscle twitches in the subjects (e.g., in proximity of the right eye or the right jaw muscles), the final stimulation intensity was decreased until the twitch disappeared. RMT procedure took place in both sessions to ensure similarity between verum and sham session from the participant's perspective. Our stimulation target was determined based on a meta-analysis by Krall et al. (2015), which found that the posterior rTPJ was recruited selectively for false-belief tasks as opposed to the anterior rTPJ which was active both during false-belief and attentional tasks. Thus, based on Krall et al. (2015) we targeted the peak coordinates in the posterior rTPJ (MNI [x=54, y=-58, z=27]) as our stimulation target. The point on the scalp above the stimulation target was therefore localized on each subject's head based on the EEG 10-10 system as a reference scheme (Herwig et al., 2003; Okamoto et al., 2004). Using the projection of standard electrodes locations on a Talairach brain template (Koessler et al., 2009) and subsequently converting them to MNI coordinates (online tool previously available at: http://sprout022.sprout.yale.edu/mni2tal/mni2tal.html), we determined that the stimulation target was located mid-way between the electrodes P6 and CP6 in a 10-10 EEG system. All our subjects wore earplugs during both verum and sham sessions. Our overall stimulation parameters was well within the established safety guidelines (Rossi et al., 2009) and subjects underwent a standardized safety screening questionnaire (Rossi et al., 2011) prior to undergoing any TMS-related manipulation.

3.2.5 Experimental procedure

Each subject was invited for two experimental sessions that took place with a 2 to 3 weeks interval (median of 14 days). One of the sessions was a verum TMS session while the other was a sham TMS session, and the order was counterbalanced across participants. In the first session, the subjects filled out a demographic questionnaire, and the Edinburgh Handedness Test (Oldfield, 1971). In each session, subjects performed the two computerized tasks. Half of the subjects always started with the Pragmatic task, while the other half always started with ToM task. Thus, overall, in the present study, task order within a session, stimulation order between sessions and attribution of stimuli list to the verum or sham condition in the Pragmatic task were counterbalanced across subjects, while response key in the Pragmatic task was randomized. Each subject was randomly assigned to each of these "condition combinations".

3.2.6 Preprocessing

Of the 28 tested subjects, three only underwent the first testing session and therefore only had data either in the sham or verum condition. One subject was fully excluded from the analysis because of not meeting the inclusion criteria of right-handedness (see Section 3.2.1) as per the Edinburgh Handedness Test (Oldfield, 1971). One was excluded in the Pragmatic task analysis and one more in the ToM Task analysis as they appeared not to have understood the task in one of the two testing sessions. 26 subjects entered the analysis for the Pragmatic and ToM task respectively.

In addition to incorrect responses in both tasks, all trials with reaction times above 3s in the Pragmatic Task and above 1.7s in the ToM task were also counted as incorrect. RTs were normalized by log10 to meet the Gaussian distribution assumption required for further statistical analysis. Normalized RTs for incorrect trials or RTs that were more than 2SD away from the condition mean of any given subject (Hartwright et al., 2012) were not analyzed.

Therefore, concerning the RT data of the Pragmatic task, an average of 5.93±3.01% SD were excluded because subjects responded incorrectly and an additional average of 3.73±0.94% SD were excluded because they were beyond 2SD from the condition log10(RT) mean. This resulted in an average of 90.34±3.03% SD of trials per subject and 5863 trials in total entering the final RT analysis.

Concerning the RT data from the ToM task, an average of 11.0±6.8% SD were excluded because subjects responded incorrectly, 3.09±1.07% SD were excluded because they were beyond 2SD from the condition mean, thus maintaining 85.91%± 6.75% SD trials per subject in the final sample, namely a total of 2707 trials entering the final RT analysis.

3.2.7 Statistical evaluation

The accuracy and log-normalized RT data were analyzed in R (RC-Team, 2019) with linear mixed models, as implemented in the *lme4* package (Bates et al., 2015). The function *lmer()* was used for continuous reaction time data whereas the *glmer()* function was used for binary accuracy data. Based on our hypothesis, the model included all our variables of interest as predictor variables. In addition to these, some putative confounds were also added to the fixed structure of the model. For the Pragmatic task these were: length of the target sentence in words (centered) and experimental session (first vs. second). For the ToM task only experimental session (first vs. second) was modelled. Finally, the model included by-subject and by-item intercepts. Sum contrast coding (i.e., [1, -1]) was used for all categorical predictors (In/Direct: direct$_{[}1]$, indirect$_{[} - 1]$; SA-matching: SA-matched$_{[1]}$, non-SA-matched$_{[-1]}$; Stimulation: sham$_{[1]}$, verum$_{[-1]}$; Session: first$_{[1]}$,

$\text{second}_{[-1]}$; Belief: $\text{B+}_{[1]}$, $\text{B-}_{[-1]}$; Desire: $\text{D+}_{[1]}$, $\text{D-}_{[-1]}$). The structure of the models is reported below in Wilkinson notation for the Pragmatic (P) and the ToM (T) tasks. The residuals were visually inspected to ensure that they met the assumptions of normality, equivariance and independence. Statistical significance of the predictors was computed based on Satterthwaite‘s method for estimation of degrees of freedom as implemented in the *lmerTest* package (Kuznetsova et al., 2017). Post-hoc tests were performed with the *emmeans()* function of the *emmeans* package (https://cran.r-project.org/web/packages/emmeans/index.html) using the implemented Tukey HSD correction for multiple comparisons.

(P) Variable ∼ In/Directness * Stimulation * SA-matching + length + session +
(1|subject) + (1|item)

(T) Variable ∼ Belief * Desire * Stimulation + session +
(1|subject) + (1|item)

3.3 Results

3.3.1 Pragmatic task

Analysis of the reaction time data in the sham condition, in absence of TMS, indicated that they were mainly affected by In/Directness and by the length of the stimulus (see Table 3.5, Figure 3.1). Direct replies were responded to more quickly compared to indirect ones ($p < 0.001$, $\beta = -0.012$) whereas length of the target sentence slowed down response times ($p < 0.001$, $\beta = 0.019$). There was no interaction between In/Directness and SA-matching ($p < 0.192$).

The analysis of the log-normalized RT data (sham and verum data together) in a larger model (see Appendix B.2) revealed an effect of In/Directness, such that reaction times to direct replies were shorter than to indirect ones (p< 0.001, $\beta = -0.011$). In addition, the length (in words) of the target utterance significantly increased the reaction time to it ($p < 0.001$, $\beta = 0.020$), while session also played a significant role such that RTs were longer in the first than in the second session ($p = 0.001$, $\beta = 0.015$). A SA-matching by In/Directness interaction was also found ($p = 0.01$, $\beta = -0.003$, see Appendix B.2 for post-hoc tests). No further effects were found significant, particularly, no effect of Stimulation as a main effect or in interaction with other predictors.

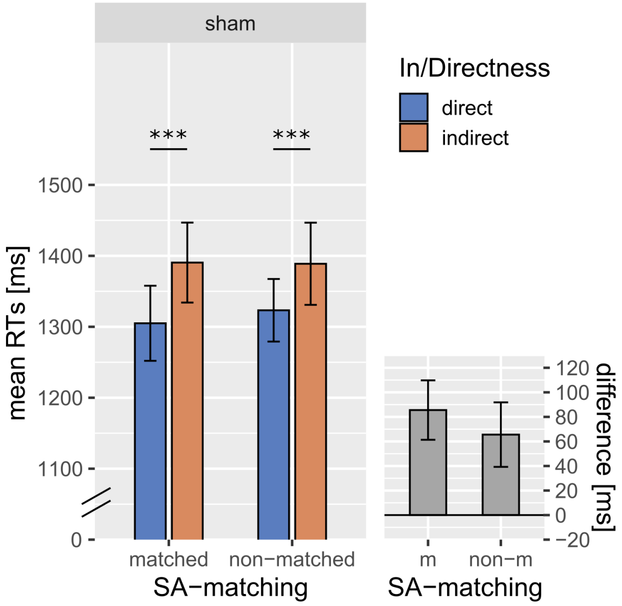


Figure 3.1: The large panel illustrates the average RTs (by subject) form the Pragmatic Task in after sham TMS plotted by SA-matching and In/Directness, illustrating the significant effect of In/Directness. The small panel illustrates the average difference in RTs found in the sham data between direct and indirect conditions (indirect-direct), separately by SA-matching. Error bars indicate the standard error of the mean (SEM) by subject. * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

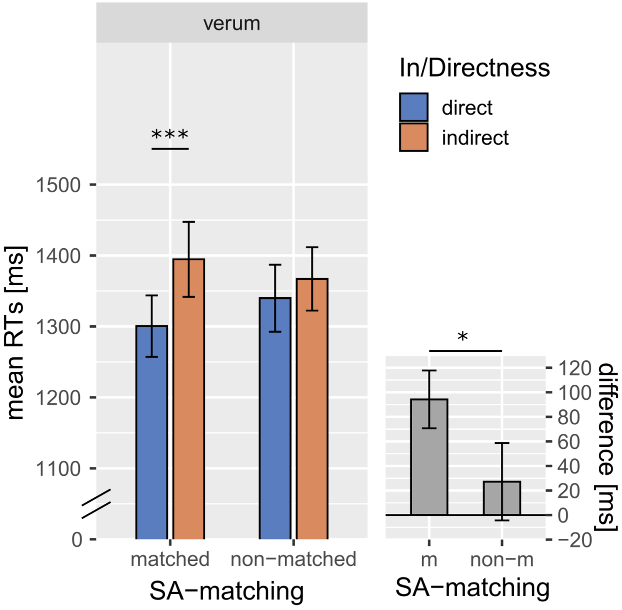


Figure 3.2: The large panel illustrates the average RTs (by subject) form the Pragmatic Task after verum TMS plotted by SA-matching and In/Directness, illustrating the significant interaction effect between In/Directness and SA-matching. The small panel illustrates the average difference in RTs found in the verum data between direct and indirect conditions (indirect-direct), separately by SA-matching. Error bars indicate the standard error of the mean (SEM) by subject. * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

Table 3.5: Fixed and random effects for the model predicting log RT data in the sham session of the Pragmatic task. Sum contrast was used for all categorical predictors (see Section 3.2.7)

RT (sham)					
log10(RTs) ~ in/directness* SA-matching + length + session + (1|subject) + (1|item)					
Fixed effects	**β**	**Std. Error**	**df**	**z-value**	**p**
Intercept	3.111	0.017	22.470	179.606	<0.001
In/Directness	-0.012	0.002	2567	-6.106	<0.001
SA-matching	0.001	0.004	123.800	0.236	0.814
Length	0.019	0.003	125.400	6.765	<0.001
Session	0.008	0.017	20.990	0.485	0.632
In/Directness : SA-matching	-0.003	0.002	2566	-1.306	0.192
Random effects	**Variance**	**Std.Dev.**			
Intercept (by subject)	0.001	0.036			
Intercept (by item)	0.007	0.081			
Residual	0.010	0.101			

Table 3.6: Fixed and random effects for the model predicting log RT data in verum session of the Pragmatic task. Sum contrast was used for all categorical predictors (see Section 3.2.7).

RT (verum)					
log10(RTs) ~ in/directness* SA-matching + length + session + (1|subject) + (1|item)					
Fixed effects	**β**	**Std. Error**	**df**	**z-value**	**p**
Intercept	3.110	0.014	26.740	219.043	<0.001
In/Directness	-0.010	0.002	2976	-5.453	<0.001
SA-matching	0.003	0.004	127	0.867	0.388
Length	0.022	0.003	128.400	7.924	<0.001
Session	0.021	0.014	23.990	1.529	0.139
In/Directness : SA-matching	-0.004	0.002	2976	-2.454	0.014
Random effects	**Variance**	**Std.Dev.**			
Intercept (by subject)	0.001	0.038			
Intercept (by item)	0.005	0.070			
Residual	0.010	0.100			

However, when analyzing the log-normalized RTs of the verum condition alone (see Tables 3.6 and Figure 3.2), similar to what we did for the sham data, we observed that the same results of the sham analysis are reproduced (effect of In/Directness $p < 0.001$, $\beta = -0.010$; length of target sentence, $p < 0.001$, $\beta = 0.022$), with the difference that we find an additional significant interaction between In/Directness and SA-matching which was not present in the sham data (p= 0.014, $\beta = -0.004$). Follow up post-hoc tests indicated indeed that in the SA-matched set, indirect replies took longer to process than direct ones ($p_{Tukey} < 0.001$), however, this was not the case in the non-SA-matched set ($p_{Tukey} = 0.167$).

Analysis of the accuracy data did not reveal any significant effects of our factors of interest nor of the examined confound factors (see Appendix B.1).

3.3.2 Theory of Mind task

The analysis of log-normalized RT data for the ToM task (see Figure 3.3 and Table 3.7) indicated a significant effect of Belief such that true Belief was processed faster than false belief ($p < 0.001$, $\beta = -0.052$) and an effect of Desire ($p < 0.001$, $\beta = -0.046$) such that approach desire was processed faster than avoidance desire. In addition, there was a significant interaction between the two ($p < 0.001$, $\beta = -0.025$, see Appendix B.4 for post-hoc tests). Stimulation also had a significant facilitatory effect of Stimulation such that sham trials had longer RTs than verum trials ($p < 0.001$, $\beta = 0.009$). Interestingly, a marginally significant three-way interaction between Belief, Desire and Stimulation ($p = 0.094$, $\beta = -0.003$) was also detected. Follow-up post-hoc tests (see full Table B.8) on this three-way interaction indicated that while verum stimulation (vs. sham) did not affect the B+D+ conditions ($p_{Tukey} = 0.950$), it did decrease reaction times in the B+D- ($p = 0.046$) and in the B-D+ ($p_{Tukey} < 0.01$) but not in the B-D-, which did not survive correction for multiple comparisons ($p_{Tukey} = 0.359$, $p_{uncorrected} = 0.029$). The confound factor of Session also had a significant effect such that RTs were longer in the first than in the second session ($p < 0.001$, $\beta = 0.014$). Consistent with the analysis of RTs, the analysis of the accuracy showed an effect of Belief ($p < 0.001$, $\beta = 0.682$) and Desire ($p < 0.001$, $\beta = 0.401$), as well as an interaction between the two ($p < 0.001$, $\beta = 0.201$) and an effect of Session ($p = 0.001$, $\beta = -0.152$). However, it did not reveal any effect involving stimulation (see Appndix B.3).

Table 3.7: Fixed and random effects for the model predicting lot RT data in the ToM task. Sum contrast was used for all categorical predictors (see Section 3.2.7).

RTs					
log10(RTs) ~ belief * desire * stimulation + length + session + (1|subject) + (1|item)					
Fixed effects	**β**	**Std. Error**	**df**	**z-value**	**p**
Intercept	2.829	0.014	25.260	200.893	<0.001
Belief	-0.052	0.002	5360	-27.998	<0.001
Desire	-0.046	0.002	5168	-24.505	<0.001
Stimulation	0.009	0.002	5377	4.924	<0.001
Session	0.014	0.002	5375	7.213	<0.001
Belief : Desire	-0.025	0.002	5362	-13.713	<0.001
Belief : Stimulation	-0.002	0.002	5359	-0.914	0.361
Desire : Stimulation	0.000	0.002	5362	-0.254	0.800
Belief : Desire : Stimulation	-0.003	0.002	5357	-1.674	0.094
Random effects	**Variance**	**Std.Dev.**			
subjID	0.005	0.071			
food	0.000	0.004			
Residual	0.018	0.136			

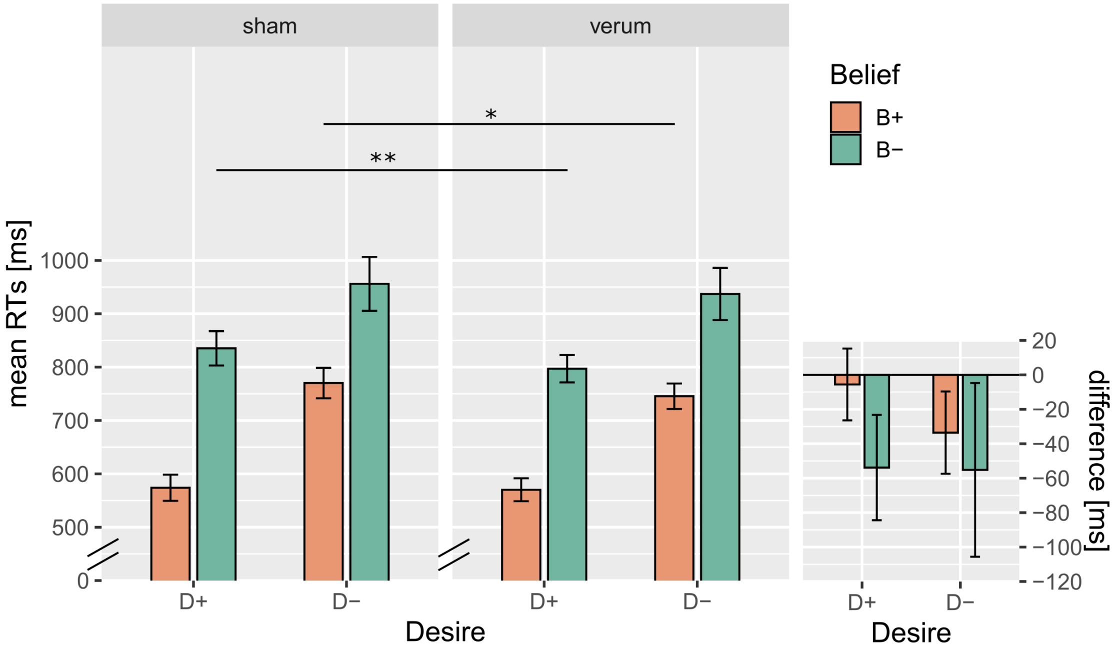


Figure 3.3: The large panel illustrates the reaction time data form the Theory of Mind task separated by Belief, Desire and Stimulation, where B+: true belief, B-: false belief, D+: approach desire and D-: avoidance desire. The small panel illustrated the difference in reaction dime between verum and sham condition (verum-sham) by Belief and Desire. In all panels, error bars indicate the standard error of the mean (SEM) by subject. (A) Average accuracies in the ToM Task. (B) Average reaction times in the in the ToM Task. Stars indicate significance level (* indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

3.4 Discussion

In the present study, we investigated whether activation in the right TPJ has a causal effect on the comprehension process of direct and indirect speech acts. We tested this in two sets of conditions. In one set, direct and indirect speech acts were performed with the same utterance but differed in their communicative function (true question answering by a *statement* vs. *acceptance/declination* of an offer), in order to mimic a design used in most current studies. The other set of conditions was speech-act matched and compared direct and indirect speech acts with the same utterance and also with the same communicative role (true question answering by *stating*), thus avoiding the confound of change in SA type. To obtain information about the participants' speech act comprehension, a Pragmatic task was applied: subjects had to decide whether the direct or indirect replies conveyed by identical sentences meant "yes" or "no" (that is, *agreement/disagreement* to a polar question or *acceptance/declination* of an offer or invitation). In the sham condition not manipulating brain activity, we found generally slowed pragmatic judgements for indirect as compared with direct conditions, independent of SA-matching. We thereby replicated established results and extended them to SA-matched indirect speech acts. However, after repetitive transcranial magnetic stimulation (rTMS) of the right temporoparietal junction (rTPJ), pragmatic judgements were equally fast in non-SA-matched direct and indirect trials, whereas the in/directness contrast was significant for the conditions matched for speech act function (SA-matched). The observed response patterns show that, under rTMS to the rTPJ, the well-established processing difference between direct and indirect speech acts is absent, but only if these are not matched for communicative function. As the processing difference between direct and indirect speech acts was still observed for items matched for communicative function, these results cannot be attributed to indirectness *per se*. In addition, we found some evidence that our TMS manipulation did affect ToM function as demonstrated by reduced RTs in a ToM task. Future studies need to investigate whether the pattern observed under rTMS in the Pragmatic task can be related to a difference in communicative function, e.g., between agreement/disagreement or acceptance/declination, or rather to a combination of speech act function and indirectness. Our data argue against a role of rTPJ in processing features specific to indirectness, such as heavy ToM load.

3.4.1 Pragmatic and ToM tasks

Pragmatic task without stimulation of rTPJ

Our first research question was whether the processing cost of indirect speech acts relative to direct ones is also present when both are matched for SA type. In absence of TMS stimulations, in the present Pragmatic task, subjects overall performed well and complied with task instruction across all experimental conditions as indicated by the average accuracy $> 90\%$ (see Appendix B.1). This high accuracy is consistent with previous studies where a task similar to ours was used and subjects had to indicate whether a given direct or indirect reply were interpreted as a ‘yes’ or ‘no’ (Feng et al., 2017; Feng et al., 2021; Jang et al., 2013). An absence of significant differences between direct and indirect conditions was also previously reported by the two separate studies by Feng et al. (2017), Feng et al. (2021). In contrast, Jang et al., 2013, who too employed the same Pragmatic task, did find indirect replies to be understood with significantly less accuracy compared to direct ones. In their task however, they did not use the same linguistic form across direct and indirect conditions. Their finding of different accuracy for direct and indirect replies might therefore be related to an absence of matching of the direct/indirect stimuli. Therefore, our study is consistent with the results of other studies Feng et al. (2017), Feng et al. (2021) that used carefully matched direct and indirect stimuli consisting of identical sentences in the direct and indirect condition, although these researchers did not report matching of direct and indirect conditions for the type of speech act used.

Concerning reaction times in absence of TMS (Figure 3.1), in our study we find that subjects were slower at responding to direct vs. indirect replies. We therefore replicate the consistent finding that indirect replies take longer to process than direct ones. Such a difference in response times was previously identified in a range of tasks including reading (Hamblin & Gibbs, 2003; Holtgraves, 1999), attribution of a ‘negative, positive or meaningless’ connotation of the reply (Shibata et al., 2011) and yes/no interpretation of the response (Feng et al., 2017; Feng et al., 2021; Jang et al., 2013), which was also applied here. However, this previous literature did not examine the potential role of SA-changes co-occurring with indirectness. Instead, they typically examined either indirect speech acts involving SA change or a mixture of indirect replies with and without SA-change. Crucially, we presently extend these findings by demonstrating that these processing delays are maintained, also when the indirect reply does not involve a change of SA function relative to its direct control. Therefore, it appears that processing indirectness requires additional cognitive processing irrelevant of SA-matching. It is possible that these additional processes are involved in the inference that is required to identify the indirectly conveyed meaning. However, a previous study has highlighted that indirect speech acts are typically less predictable, less semantically similar to their context question, less coherent with their context question and understood with less certainty compared to direct ones conveyed by the same utterance (Boux et al., 2023). Each of these features and any combination between them, as well as differential ToM involvement, could be at the basis of a relatively higher difficulty or load in processing indirect speech acts, as indexed by prolonged reaction times. The exact cause of such processing differences however cannot be revealed by reaction times data alone and is discussed in the next sections.

Pragmatic task after stimulation of the rTPJ

For the reaction times obtained after verum TMS, a two-way interaction emerged between In/Directness and SA-matching that was not present in absence of TMS (i.e. sham condition). Indeed, when the rTPJ was stimulated with TMS, the difference in reaction times between the indirect and direct replies was preserved in the SA-matched set whereas a corresponding difference for the non-matched set was not reliable (Figure 3.2). This can be seen as evidence that, after rTMS to the rTPJ, the well-known effect of indirectness effect on response times is not present if the direct and indirect conditions are not matched for speech act function. However, with matched speech act type, the indirectness difference is present similar to the results in the sham condition, where magnetic stimulation is ineffective. As there is an interaction effect after verum rTMS which is not seen in the sham condition, these data suggest that rTMS to rTPJ changes the normally seen patterns only in case indirectness is accompanied by a change in communicative function. Therefore, these results can be used to argue for a relevance of rTPJ for SA-nonmatched in/directness.

One may question the above interpretation by pointing to the larger statistical analysis involving both sham and verum conditions together. In this case, the three-way interaction between in/Directness, SA-matching and Stimulation did not reach significance. This is a limitation, given that such a significant three-way interaction would have provided the strongest evidence for a differential effect of TMS on direct and indirect SA-matching and –mismatching communicative actions. It is possible that that the sample size of the present study was not sufficient to achieve sufficient statistical power for obtaining a significant 3-way interaction effect. Note that, in absence of openly available pre-existing data on this topic, a power-analysis during study planning was not possible. Similarly, the difference between RTs to non-SA-matched direct and indirect replies after verum stimulation was not statistically significant with $p_{Tukey} = 0.167$. Here again, we cannot exclude that this difference would have been significant with a larger sample size. However, the pattern of results obtained provides some indication regarding the role of rTPJ in comprehension of indirectness. Namely, we do not find evidence that rTPJ is causally involved in comprehension of indirectness *per se*. If this were the case, the reaction time differences between direct and indirect replies would not have been detectable neither in the SA-matched nor in the non-SA-matched set after stimulation. Instead, we only find evidence verum TMS, when rTPJ was stimulated, the comprehension of the indirect replies in the non-SA-matched set was affected. Whether indirectness co-occurred with a change in speech act seems therefore to be a key element in explaining our results. We therefore suggest that after rTPJ stimulation, SA-matched indirect replies behaved in the same way as documented in the literature and in our present sham experiment, but that, under rTMS, not-SA-matched ones failed to show this difference normally reported. in the absence of a significant triple interaction, we interpret this as some, although moderate, evidence for a role of the rTPJ in contributing to the processing difference between not-SA-matched direct and indirect speech acts.

Theory of Mind and stimulation of the rTPJ

Our final question was whether alterations in reaction times to non-SA-matched indirect replies induced by TMS stimulation to the rTPJ can be related to ToM processing. Before addressing this question, the results of the ToM task will be briefly discussed. The ToM task submitted to our subjects captured two classic components of Theory of Mind, i.e., processing of (true/false) beliefs and processing of (approach/avoidance) desires (Leslie et al., 2004; Premack & Woodruff, 1978; Wellman & Liu, 2004). As expected, false belief trials (B-) were more difficult to process than true belief trials (B+) and avoidance desire (D-) trials were more difficult to process than approach trials (D+) and were associated with longer reaction times and lower accuracies. Furthermore, we found an interaction effect between belief and desire, such that trials combining a false belief and an aversive desire (B-D-) took particularly long to process (see Figure 3.3). Thus, we successfully replicated the known effects associated with this specific task and other variants thereof (Apperly et al., 2011; Hartwright et al., 2012, 2014; Hartwright et al., 2016) indicating that these two aspects of ToM processing, processing of beliefs and of desires, require a cognitive effort. Importantly, this also indicate that our task was effectively implemented. In addition, we find several indicators that our TMS manipulation successfully affected ToM processing. Indeed, a marginally significant effect of TMS stimulation was detected in the reaction times measures. Importantly, stimulation decreased reaction times in trials involving avoidance desire (B+D-) and false belief (B-D+) – namely those involving ToM processing – but not in the control condition (B+D+), which remained unaffected. In spite of a numeric difference, the effect of stimulation in the condition involving both avoidance desire and false belief (B-D-) was not significant after correction for multiple comparison. It is possible that the combined ToM condition did not only require higher engagement of ToM, but also of other processes (e.g., attention), which could potentially have made the data more variable (note indeed larger error bars for the B-D- condition in 3.3), which in turn could have made the TMS effect more difficult to detect, resulting in only a marginal significance.

Stimulation of rTPJ

An important aspect of our results that needs to be addressed is the directionality of the effects. It was surprising, on first view, that, compared to the sham condition, TMS to the rTPJ was associated with a decrease, rather than an increase, in the reaction time difference between the indirect and direct replies in the non-SA-matched set. It was equally surprising that the stimulation reduced reaction times in the critical trials of the ToM task. In fact, the stimulation protocol used in the present study (i.e., 1 Hz TMS pulses for 25 min) is expected to produce inhibition in the targeted brain area (Fitzgerald et al., 2006; Silvanto & Cattaneo, 2017) and previous studies directing TMS to the rTPJ consistently found that 1Hz off-line TMS protocol produced inhibitory effects on ToM function or on other aspects of social cognition (Baumgartner et al., 2014; Costa et al., 2008; Giardina et al., 2011; Young et al., 2010). However, an alternative possibility is what is sometimes called “paradoxical facilitation”, i.e., the detection of behavioral facilitation after an inhibitory TMS protocol, which is a known to occur in non-invasive brain stimulation research (Najib & Pascual-Leone, 2011; Théoret et al., 2003). Even though this does provide a deeper explanation for why the reverse effects are present in our two task, it shows that similar apparently paradoxical reverse effects are not an exception in TMS research. Importantly the fact that patterns consistent with facilitation were found in both our ToM and Pragmatic task is indeed consistent with a "paradoxical facilitation" of the stimulation.

3.4.2 Speech acts, indirect speech acts and Theory of Mind

In the Pragmatic task, we used a well-matched stimulus set (see Table 3.2 and 3.3) where direct and indirect replies were conveyed by the very same linguistic form and we applied a within-subjects experimental design. Additionally, we find some parallels between TMS-associated alterations of performance in the Pragmatic and TMS-induced alterations in the ToM task. These are consistent with the involvement of ToM in comprehension of non-SA-matched speech acts (but not of matched ones). How can this different pattern of results be explained? The rTPJ might be causally and specifically involved in the non-SA-matched set, possibly due to the specific type of communicative action performed by these indirect replies – in other words, speech act type (Searle, 1979). Specifically, ToM might play a role in processing the additional shared assumptions such as beliefs and intentions of the speaker that are necessary to infer the intended communicative motive. In this regard, healthy adults are known to keep track of the state of knowledge of other people during conversation (Rueschemeyer et al., 2015) also when they are not explicitly instructed to do so (Jouravlev et al., 2019). In case of non-SA-matched indirect replies, a closer assessment of the common ground between the conversational partners might be required to infer the communicative function of *accepting* or *rejecting* an offer/invitation compared with an *assertive* speech act and therefore result in a greater ToM load. In sum, it is possible that non-SA-matched indirect replies in this set carried out speech acts that are particularly reliant on ToM and that were thus sensitive to the TMS to rTPJ manipulation, while SA-matched ones were not.

In the light of these considerations and of the findings of the present study, a reinterpretation of the past literature could be considered. As already argued in the introduction, much of the past research did not systematically take SA-matching as a relevant factor in their experimental design. In fact, most, or even all of the stimuli used were indirect speech acts that co-occurred with SA-change. (We write "most", because, for some studies, the methods descriptions do not include sufficient information about speech act type). No previous study reported to have performed the SA matching we argue is necessary to unconfound studies of indirectness. Interestingly, these studies find direct associations between indirect language processing and ToM either directly, by behavioral correlations (Champagne-Lavau & Joanette, 2009; Champagne-Lavau & Stip, 2010; Trott & Bergen, 2018) or indirectly, by finding the ToM brain network to be active during comprehension of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2012). A neurostimulation study targeting rTPJ using tDCS also found evidence consistent with a causal role of this region for comprehension of indirect speech acts, via a modulation of ToM function (Feng et al., 2021).The present finding that SA-matching might play a role in the involvement of ToM is compatible with the findings of these previous studies, and potentially offers a different interpretative key. Namely, it appears possible that at least some of the ToM activation found in the previous studies could have been in fact due to contrasting different speech act types at the direct and indirect level. In other words, these might reflect differences in processing of the speech act types rather than differences in processing indirectness *per se*. This view becomes particularly plausible if one considers the difference between speech acts as, for example, *statements* on one hand and other speech acts such as *excuses*, *promises*, *negative opinions*, etc. on the other. If I tell someone who asked about it that China is far away, this communication may involve little ToM processing. However, if I use the same sentence to justify my postponement of an important business trip, quite a bit of thinking about possible partner responses, including thoughts and plans, seems likely. Therefore, it is evident that different communicative actions, even entirely direct ones, come with different ToM load.

When looking at the broader picture, in contrast with a series of authors seeing ToM as having a central role in non-literal language processing (Cummings, 2015; Enrici et al., 2019; Sperber & Wilson, 1996, 2002), other have proposed more nuanced accounts, favoring the view that different non-literal language phenomena might rely on ToM to different degrees, such that some phenomena might possibly not require specific ToM contribution (Andrés-Roqueta & Katsos, 2017; Bosco et al., 2018; Domaneschi & Bambini, 2020; Jary, 2013; Kissine, 2016), beside what is usually required by language processing. Our present findings are compatible with the rTPJ being relevant specifically for comprehension of indirect speech acts co-occurring with a speech act change relative to their direct controls. We also find that the rTPJ might contribute to the comprehension by supporting ToM function. An involvement of rTPJ-mediated ToM in comprehension of indirectness *per se* would have been demonstrated only by finding an effect of TMS on behavior both in the SA-matched and non-SA-matched studies. Indeed, the SA-matched set was the only condition that had indirectness fully isolated from other factors such as SA-change.

While this result is in in principle in line with the predictions deriving from a possible account of indirect speech act comprehension that does not require additional ToM, it is also compatible with rTPJ-mediated ToM contributing causally to the comprehension of indirectness in both cases, but more so when a SA change co-occurred. In such a scenario where the non-SA-matched indirect speech acts depend on ToM even more than SA-matched ones, the TMS manipulation might have affected only the more “ToM greedy” condition but not the SA-matched ones. To sum up, while we cannot speak to the larger question of a specific involvement of ToM in indirect speech acts, we do find some support for the necessity of rTPJ-mediated ToM for processing of speech act-specific assumptions or to the change in speech act function.

So, we know that speech act matching has an effect on the cognitive (Boux et al., 2023) and, as suggested by the present data, on neuronal processes underlying comprehension of indirectness. We also know that different (direct) speech act types have been shown to be associated with different neural signatures, sometimes involving substantially different sets of cortical areas (Boux et al., 2021; Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019; van Ackeren et al., 2012; van Ackeren et al., 2016). It therefore seems that the so far common experimental approach of comparing direct speech acts used to carry out a certain communicative function with indirect ones that are used to realize a different communication function might not be the best experimental approach. This type of contrast might, together with the neurocognitive basis of indirectness, also capture a certain SA difference, which can act as a confound factor. We suggest that future research should be conducted in awareness of this confound. Ideally, SA-type should be controlled for by examining direct and indirect speech acts carrying out the same type of communicative action. Alternatively, our present approach could also be taken, having different sets of SA-matched and SA-unmatched direct and indirect stimuli. In addition, specificity and transparency of the methods section regarding the types of SAs carried out directly and indirectly would be desirable to facilitate comparability between studies and could be achieved by having these reported systematically.

3.4.3 Conclusion

In the present study, we asked whether previously reported findings about processing differences between direct and indirect speech acts can indeed be attributed to in/directness. A review of the literature shows that, in most or all previous work, the in/directness difference was confounded by the use of different speech act types in the direct and indirect conditions (e.g., *statements* vs. *requests*). Therefore, we here compared conditions in which the speech act performed directly and indirectly were not matched for speech act function, as in the previous work, to novel conditions in which direct and indirect communicative actions were performed with the same sentence and speech act type. The findings are as follows: (1) in absence of TMS, we replicate that indirect speech acts take longer to process than matched direct controls for non-SA-matched conditions and extend this finding to SA-matched ones. (2) After repetitive transcranial magnetic stimulation of the right temporal junction, rTPJ, a brain site thought to be important for theory of mind processing, the response time difference between non-SA-matched indirect and direct communicative actions is absent, which is consistent with a role of the stimulated cortical region in indirect SA processing. (3) However, there was no comparable pattern after TMS when direct and indirect conditions were matched for speech act function. SA-matched direct and indirect conditions showed the same significant response time difference with TMS as without. This result argues against the possibility that the rTPJ is important for indirectness processing *per se.* (4) The TMS manipulation facilitated processing in the critical trials in a ToM task, a finding consistent with a role of this area in ToM processing. We conclude that the rTPJ is causally involved differentially in indirect vs. direct speech act processing, but only if an additional difference in speech act function is present. Therefore, the role of this region seems not specific or indicative of indirectness *per se.* Our results suggest that activation of ToM systems found in previous neuroimaging studies for comprehension of indirectness might likewise be, at least in part, due to co-occurring SA changes. Our work comes with the methodological implications for future studies of indirectness that it is essential to match not only for critical linguistic structures – the words and sentences used as tools to perform direct or indirect communicative actions - but to match, in addition, for the type of speech act too, as different speech acts come with different requirements on calculating the knowledge and commitments and other mental states of communication partners.

Chapter 4

Cognitive Features of Indirect Speech Acts

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Abstract

The offer of some cake can be declined by saying “I am on a diet”– an indirect reply. Here, we asked whether certain well-established psychological and conceptual features are linked to the (in)directness of speech acts – an issue unexplored so far. Subjects rated direct and indirect speech acts performed by the same critical linguistic forms in different dialogic contexts. We find that indirect replies were understood with less certainty, were less predictable by, less coherent with and less semantically similar to their context question. These effects were smaller when direct and indirect replies were matched for the type of speech acts for which they were used, compared to when they were not speech act matched. Crucially, all measured cognitive dimensions were strongly associated with each other. These findings suggest that indirectness goes hand-in-hand with a set of cognitive features, which should be taken into account when interpreting experimental findings, including neuroimaging studies of indirectness.

4.1 Introduction

In day-to-day situations, people often communicate in an indirect manner. For instance, exchanges such as “Would you like to have dinner at a steakhouse?”, followed by the reply “I am vegetarian” occur often and are seamlessly understood. In the present case, the reply is understood as implicating (+>) a “no”. From a theoretical perspective, indirect speech acts have been described as cases of language use where a speaker who *“utters a sentence, means what he says, but also means something more”* (Searle, 1979). In this perspective, indirect speech acts allow the speaker to perform one speech act and in addition perform another one. On Searle’s account the listener then infers what the intended additional meaning of the speaker was by using general world knowledge, but also by assuming cooperativeness of the speaker as well as assuming his/her contributions to be relevant. Similarly, Grice attempts to provide a rational framework to explain how indirect speech acts are comprehended (Grice, 1975). He also proposes that conversational success is based on its cooperative nature, implicating that all communicating partners are cooperative and assume the same of each other. In Grice’s words, this means that they follow a communicative principle to *“Make [their] contribution such as is required, at the stage at which it occurs, by the accepted purpose or direction of the talk exchange in which [they] are engaged”* (Grice, 1975). This further implies that speakers follow several communicative maxims, including the maxim of Relation (Grice, 1975), and say things that are relevant for the scope of the conversation, rather than producing utterances that are unconnected to each other. In Grice’s cooperative framework indirect speech acts (which lead to Relevance Implicatures) are those speech acts that *prima facie* appear to violate the principle of Relation, but in fact do not on second view. The “irrelevance” is only apparent, as the implied (second) meaning conveyed by the utterance is in fact relevant for the ongoing conversation. Another peculiarity of indirect speech act is that the implicated content is not logically entailed by the literal meaning of the same utterance. So, the reply “I am vegetarian” in the example above conversationally implicates that the addressee does not want to join the person who made the offer to visit the steakhouse, although it does not logically imply (entail) it. Finally, indirect speech acts are strongly context-dependent, where context is meant in a broad sense, thus including immediate physical context, linguistic context and background knowledge or common ground. In our example “I am vegetarian” would hardly ever be understood as a declination if the linguistic environment similar to the context sentence “Would you like to have dinner at a steakhouse?” were absent. The outlined features suggest that a range of different cognitive properties distinguish direct from indirect speech acts.

The phenomenon of indirectness has been the object of attention also in the field of psycho- and neurolinguistics. Comprehension of the intended indirect meaning is thought to be the result of a process of inference that allows the comprehender to go beyond the (often irrelevant) literal meaning and find the relevant non-literal one. The exact mechanisms underlying the processing and understanding of indirect speech acts have been the object of debate and research, resulting in several cognitive accounts (Standard Pragmatic Model inspired by Grice, 1975 and Searle, 1979; Direct Access Hypothesis, Gibbs, 2002; Graded Salience Hypothesis, Giora, 1997, 2002; Relevance Theory, Sperber and Wilson, 1996; see Meibauer, 2019 and Ruytenbeek, 2021 for a review of open issues). In addition, experimental studies focusing on the neural (and other physiological) correlates of indirectness assessed which processing delays characterise indirectness and which brain areas engage specifically in the processing of indirect (as compared to direct) speech acts. These studies highlighted how indirect replies elicit different EEG (Coulson & Lovett, 2010) and pupillary responses (Tromp et al., 2016). Overall, they showed relatively consistently that two major brain networks were active when indirect replies were contrasted with direct replies (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2016). The first network involved areas such as the medial prefrontal cortex (mPFC), the left and/or right temporoparietal junction (TPJ) and the precuneus. These activations were interpreted as being part of an inferential process eventually allowing the listener to understand the communicative intention of the speaker (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011). The second network, which is consistently found active with the same contrasts, groups together several bilateral cortical areas that have been related to language such as the inferior frontal gyrus (IFG) and the middle temporal gyrus (MTG) as well as the temporal poles (TP). These were interpreted as involved in processing greater demands for coherence building in order to construct the situation model and semantic binding to allow bridging larger semantic gaps between the indirect reply and its context (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2016).

However, in order to study the mechanisms of indirectness comprehension both at the cognitive and neural level, it is essential in the first place to understand in which ways indirectness differs from directness. Interestingly, a systematic quantitative study of how direct and indirect speech acts are perceived and which cognitive properties distinguish them from one another is still not available. In particular, interpretation of the results provided by neuroimaging studies have a limited scope if no information about the cognitive properties of indirect vs. direct speech acts is available. For instance, the above-mentioned studies interpreted greater activation in the right MTG and right IFG as a result of the greater effort required to achieve a coherent reading in the case of an indirect reply. This interpretation rests on the fact that other studies have established that these very same areas play a role in coherence building and on the intuition that indirect replies might be less coherent with their context than direct ones (reverse inference; Poldrack, 2006). However, a crucial piece of information is missing. That is, it has not been shown yet that indirect replies actually have a lower coherence with their context than direct ones. Only once such information is provided, can the claim that indirectness processing requires a greater engagement of coherence-building efforts be fully justified. In a similar fashion, other properties of indirectness might need to be characterised in order to better understand how processing of indirectness engages certain neural and /or cognitive mechanisms. Therefore, the goal of the present study is to characterise (at least some of) the cognitive properties of indirectness, such that investigations of cognitive and neural mechanisms of indirectness comprehension can be informed.

In the previous section, we have provided classical definitions of indirect speech acts (or Relevance implicatures) by Searle and Grice. These definitions allow to set up certain hypothesis about how direct and indirect speech acts can be differently perceived. In particular, if indirect speech acts are context-dependent, then the relationship between direct and indirect speech acts and their respective linguistic context might systematically differ, which in turn might affect the cognitive processes engaged during comprehension of indirectness. Based on Grice, indirect speech acts are the result of an apparent violation of a maxim. In other words, they seem not to satisfy a tacit "rule" that typically constrains communication. Therefore, we hypothesise that indirect replies might be less predictable than direct ones. In addition, it is specifically the Maxim of Relevance that is apparently violated by indirect speech acts. This means that the utterances used to perform an indirect speech act might appear to be semantically unrelated or disconnected from their context. Therefore, we hypothesise that indirect speech act might be less coherent and less semantically related to their context. Finally, as the non-literal message conveyed by the means of an indirect speech act is not entailed (but only implicated following an inferential scheme) by the literal interpretation of the utterance, it is possible that it is interpreted with less certainty compared with a direct reply. As these four dimensions of predictability, semantic relatedness, coherence and interpretative certainty might be related to the linguistic definition of indirectness, we also hypothesise that they correlate with one another. Importantly, these four properties are also known to be associated with specific patterns of brain activity (see Section 4.4, "Discussion"), which might also be detected in neuroimaging studies of indirect speech act comprehension. As such, they are of particular importance given our aim to inform neuroimaging research. Please note that, whereas some of the features mentioned, e.g., coherence, are sometimes discussed in interpretations of experimental work, others, including predictability and interpretative certainty, are rarely taken into account (see Section 4.4, "Discussion"). Additionally, neuroimaging studies have focused on neural correlates of indirectness from different points of view. Whereas some of these focused on specific cases of indirectness, for instance, indirect utterances used to convey a *request*/directive speech act (Coulson & Lovett, 2010; Tromp et al., 2016; van Ackeren et al., 2012), other examined neural correlates of indirectness using a broader variety of stimuli used to convey various types of communicative intention and, therefore, speech act functions (or illocutionary forces), such as *statement*, *request*, *opinion expression*, disclosure, *request refusal*, *excuse*, etc. (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2016). Finally further studies examined indirect speech acts depending on whether or not they had a face-saving effect (Bašnáková et al., 2015; Bašnáková et al., 2014), namely based on whether the use of indirectness had the effect to make an utterance more polite and more socially acceptable as in the case of indirect excuses, indirect *refusals* or indirect *negative opinions*. However, none of the previous experimental neuroimaging studies of indirectness reported that they matched the speech act function between direct and indirect conditions. Looking at the example stimuli given in some of the well cited works it appears that some studies had a mixture of matched and unmatched stimuli, but did not have this property as a factor in their analysis (Bašnáková et al., 2015; Bašnáková et al., 2014), while others appeared to have only unmatched stimuli (van Ackeren et al., 2012). Thus, the effect of the presence or absence of SA-change co-occurring with indirectness has never been manipulated in a controlled fashion within the same study nor it was the object of systematic investigation. This factor is however susceptible to affect neural mechanisms involved in the comprehension of indirectness, given that different types of speech acts have been shown to be associated with different neural signatures (see e.g. Boux et al., 2021; Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019). We therefore decided to create two sets of stimuli: one in which this confound was removed, namely where direct and indirect conditions performed the same speech act type, and another with "non-SA-matched" in/direct speech acts, as they have commonly been used in neurocognitive studies. Here follows a more detailed explanation of this important difference. If we take the reply "I am healthy again", it could be read as a direct reply in the context of the question "Have you still got a cold?", and it could also be read indirectly in the context of the question "Are you still taking these pills?". In both cases the reply, while conveying different messages, has an *assertive* communicative function (Searle, 1979), namely the function of describing a state of affairs. There is therefore no change of speech act type co-occurring with indirectness. Let's now take a different example. The reply "I am vegetarian" is read as a direct reply with an *assertive* communicative intention in the context of the question "Do you eat meat". However, when read in the context of the question "Would you like to have dinner at a steakhouse?", it is interpreted as the *declination* of an *offer* (commissive speech act; Searle, 1979). In this latter case, indirectness co-occurs with a change in speech act type.

In the present study, we separately examined indirect replies with and without changes in speech act type, as the co-occurrence of change of speech act type might possibly require different cognitive mechanisms. For instance, it might require additional processing as, above and beyond the mere propositional content of the utterance, also the speech act type has to be inferred and recalculated. We therefore hypothesised that indirect replies with speech act change might differ more substantially from their direct counterparts than would direct and indirect twins matched for speech act function. The additional differences would then be attributable to the additional difference in speech act function. Nevertheless, we still expected indirect replies to be rated markedly differently from direct ones, and to be attributed relatively lower Coherence, Predictability, Semantic Similarity and interpretative Certainty.

To sum up, our aim for the present study was to assess whether there are systematic differences in how direct and indirect replies are perceived. We studied direct and indirect replies which, were conveyed by the same linguistic form but acquired a direct/indirect pragmatic status based on the preceding context question. This approach is similar to the methodology used in recent neurocognitive studies (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; van Ackeren et al., 2016) and therefore maximizes comparability of the resulting findings. Additionally, we assessed whether these properties were affected by whether indirectness was co-occurring with a change of speech act type relative to the direct response, a factor that was not systematically examined so far. To this scope, we used two different sets of stimuli, one where indirectness occurred with (non-SA-matched) or without (SA-matched) a change in speech act type relative to its direct interpretation. Importantly, our stimulus material was created following established linguistic definitions of indirectness (see above and see Section 4.2, "Materials and Methods"). We then asked participants to rate the direct and indirect replies on the cognitive dimensions of Certainty of interpretation, Coherence with the context question, Semantic Similarity to the context question and Predictability. We therefore examined whether theoretical linguistic notions were reflected by how lay subjects perceive indirectness. In addition, to check for congruency between the established linguistic criteria used for stimulus generation and the subjects' understanding of "direct" and "indirect" replies, we asked participants to rate the property of Directness. Finally, we asked whether all these rated properties were in close association with one another and, in particular, whether they were consistently tied to indirectness.

4.2 Materials and Methods

4.2.1 Subjects

Twenty-eight healthy adult volunteers (11 males, 16 females, 1 diverse) took part to our study. They were on average 25.5±4.8 SD years old (median = 24, range = [20, 33]) . All subjects were right-handed (average LQ was 80.4±19.4 SD), as assessed by the Edinburgh Handedness Test (Oldfield, 1971), did not report having any psychological or neurological disorder and had normal or corrected-to-normal visual acuity. Additionally, they were all native speakers of English, which was also the only language that they spoke at native level. The study was carried out in accordance with the Helsinki Declaration after ethical permission had been obtained from the Ethics Committee of the Charité Universitätsmedizin, Campus Benjamin Franklin (Berlin, Germany). All participants were recruited via advertisement on campus. They all signed an informed consent form prior to the beginning of the experiment and received a monetary compensation of 10 EUR/hour. The entire session including net task time, breaks, instructions and administrative forms was always rounded-up to the full hour and therefore compensated with 30 or 40 EUR.

4.2.2 Stimuli

Individual stimuli were minimal dialogues consisting of two utterances, a question (interrogative) sentence uttered by partner A (henceforth the "context question") and a reply, a declarative sentence uttered by partner B (henceforth the "critical" reply). Each reply was preceded by one of two alternative context questions, which defined whether the critical reply was direct or indirect. All question sentences were yes/no (polar) questions. Therefore, all replies could be interpreted either as a "yes" (henceforth positive polarity items) or as a "no" (henceforth negative polarity items) to the question. Note that the label positive/negative polarity items only reflects their interpretation as "yes" or "no" answer in the present study and is completely unrelated to the linguistic property of polarity, which instead denotes a distributional property of certain lexical items across affirmative and negative sentence types (Baker, 1970). In selecting sentence pairs for direct and indirect speech acts, we followed the classic criteria of Grice (Grice, 1975) and others (Levinson, 1983; Searle, 1979). Specifically, indirect replies were defined as (i) an apparent violation of Grice's principle of Relation with respect to the context question (Grice,

Table 4.1: Examples of stimulus material in the two sets and in the direct and indirect condition, respectively. Note that in the SA-matched and the non-SA-matched sets both “yes” and “no” polarity items where present in equal amounts.

	CONDITION	QUESTION	QUESTION’s SA	CRITICAL REPLY	REPLY’S SA	POLARITY (EXPECTED RESPONSE)
SA-matched	direct	**Is your cat hurt?**	information query	**It got wounded.**	providing information	yes
	indirect	**Are you bringing your cat to the vet?**	information query		providing information	yes
non-SA-matched	direct	**Have you decided on a destination?**	information query	**We are not sure where to go yet.**	providing information	no
	indirect	**Shall I buy the train tickets?**	Offer (or proposal)		Rejecting (or accepting) the offer	no

1975), (ii) performing one speech act by the way of performing another (Searle, 1979) and (iii) implicating a non-literal level of meaning that is not entailed by the literal sentence meaning by which it is conveyed (Levinson, 1983). In contrast, direct replies were defined as not fulfilling the criteria (i)-(iii), while providing a straightforward literal reply to the context question.

Two different sets of stimuli, speech act matched (SA-matched) and non speech act matched (non-SA-matched), were used that differed in the speech acts they conveyed. Let’s first address the commonality between the Sets and then their differences. The direct condition was constructed identically in the two Sets and consisted of a question whose communicative function (i.e., speech act type or illocutionary force) was *querying information* and a subsequent affirmative whose communicative function was an *assertion* providing that factual information. For instance, question such as “Is your cat hurt?” or “Have you decided on a destination?” were followed respectively by the replies “It got wounded.” and “We are not sure yet”. However, the two Sets differed in their indirect condition. In the SA-matched set, the indirect condition consisted of a context question whose function was again *querying information* (e.g. “Are you bringing your cat to the vet?”) and of an indirect reply (e.g. “It got wounded”) which conveyed an indirect *assertive* speech act (+> Yes, I am bringing my cat to the vet). Therefore, within the SA-matched set, the only difference between indirect critical replies and the complementary direct critical replies was the in/directness of the critical replies, as, importantly, both still conveyed assertive speech acts. On the contrary, in the non-SA-controlled set, the indirect condition consisted of a question which conveyed an *offer/proposal* speech act, whereas the reply conveyed a speech act of *accepting* (in one half of the stimuli set) or *rejecting* the *offer/proposal* (in the other half of the stimuli set). For instance, the sentence "Shall I buy the train tickets?" was followed by the critical reply "We are not sure where to go yet." implicating a *rejection* of the offer (+> No, don't buy the tickets). The critical replies in the non-SA-matched set were thus *assertive* speech acts in the direct condition but conveyed a different speech act type (e.g. offer *declination*) in the indirect condition. Therefore, in the non-matched case, the difference between the direct and indirect replies was not exclusively constituted by their in/directness, but, in addition, by their type of speech act. Stimuli examples for both the SA-matched and the non-SA matched set are provided in Table 4.1.

All context questions and critical replies consisted of a single clause with a length between 3 and 8 words (see Table 4.2) and the critical reply was the same in both direct and indirect experimental conditions, thus being identical in all relevant psycholinguistic variables including length, bi-/trigram frequency, lemma frequency. However, to exclude potential context effects due to surface similarity between context questions and critical replies in the direct and indirect condition, the conditions were matched for various additional variables (see Table 4.3), namely length in words of the context question, pronoun repetitions between context question and critical reply, number of coreferences between the context questions and the critical reply, number of repeated lemmas between context questions and critical replies as well as cosine similarity between semantic vectors computed for the context questions and the critical reply. Cosine similarity is a measure of distributional semantic similarity between individual words or larger bits of texts which is based on Latent Semantic Analysis (LSA). LSA is a statistical method which, after training on a corpus, allows to represent any word (as long as it was provided during training) as a vector indexing the distributional properties of the item across many texts in a multidimensional semantic space. Also, novel combinations of these words (e.g., sentences), which were not part of the training corpus, can be represented as vectors in this semantic space by adding the vectors of their individual component words. Thus, the semantic similarity between two sentences is conceptualised as the cosine of the angle formed by the two vectors corresponding to the sentences of interest (Landauer et al., 1998; Landauer et al., 2007). In the present study, the cosine similarity between question and reply was obtained from the online tool, http://lsa.colorado.edu/, selecting the term-to-term comparison and applying it to the tasaALL semantic space (300 semantic dimensions). The corpus on which distributional measures were calculated included written language coming from different types of documents including novels, newspaper articles and other texts, which were estimated to correspond to the reading level up to a fist-year college student (Landauer et al., 2007).

Table 4.2: Questions used to prompt the rating of each of the measured dimensions, together with their respective anchors. Note that the Certainty dimension was not rated directly by the subject, but derived from the Function ratings, and is therefore not shown in this table.

	SA-matched (n=72)		**non-SA-matched (n=66)**	
	Yes (n=36)	**No (n=36)**	**Yes (n=33)**	**No (n=33)**
Length critical utterance in words (mean ± SD)	5,50 ± 1,54	5,19 ± 1,17	5,85 ± 1,23	5,52 ± 1,46
Number of content words in critical utterance (mean ± SD)	2,75 ± 1,02	2,69 ± 0,62	2,82 ± 0,92	2,61 ± 0,86

Each stimulus set consisted of 76 critical replies each of which could be presented in the direct or indirect condition. Half of them was to be interpreted as a “yes” (positive polarity items) and half as a “no” (negative polarity items), with the same critical reply maintaining the same polarity in both conditions. All above mentioned properties were matched between the eight conditions resulting from the crossing of the factors of SA-matching [SA-matched, non-SA-matched], Polarity [yes, no] and In/Directness [direct, indirect]. Although a small number of items had to be excluded from the analysis (see below for details), it was made sure that the final item sets used for evaluation remained well-matched for the above mentioned properties, as reported in Tables 4.2 and 4.3). Specifically, differences in length of critical reply and in number of content words in the critical replies were tested with a 2 × 2 ANOVA with factors SA-matching [SA-matched, non-SA-matched] and Polarity [yes, no] and were not significant (all main and interaction effects had $p > 0.05$). Differences in cosine semantic similarity and length of context question between conditions were also not significant as assessed by a 2 × 2 × 2 mixed ANOVA with factors SA-matching [SA-matched, non-SA-matched], In/Directness [direct, indirect] and Polarity [yes, no] (all main and interaction effects had $p > 0.05$). Number of repeated pronouns, number of coreferences and number of repeated lemmas were also comparable between conditions, as assessed by likelihood-ratio chi-squared tests applied to all (12) relevant pairwise comparisons (all $p > 0.05$). As all the indicators of semantic relatedness between context question and reply in the various conditions did not differ, we assumed that the degree of semantic relatedness of direct and indirect sequences were comparable.

Table 4.3: Psycholinguistic properties defining the relationship between the critical replies and their context question (after exclusion of a few items, see Material and Methods section). The items are split by SA-matching (SA-matched, non-SA-matched), Polarity (Yes, No) and In/Directness (Direct, Indirect). The number of items (n) is indicated for each condition. Note that the two Sets differ in their number of items.

	SA-matched (n=144)				**non-SA-matched (n=132)**			
	Yes (n=72)		**No (n=72)**		**Yes (n=66)**		**No (n=66)**	
	Direct (n=36)	**Indirect (n=36)**	**Direct (n=36)**	**Indirect (n=36)**	**Direct (n=33)**	**Indirect (n=33)**	**Direct (n=33)**	**Indirect (n=33)**
LSA Cosine similarity (mean ± SD)	0,67 ± 0,13	0,65 ± 0,17	0,64 ± 0,15	0,64 ± 0,13	0,67 ± 0,12	0,66 ± 0,13	0,64 ± 0,12	0,63 ± 0,12
Length context question in words (mean ± SD)	5,67 ± 1,20	5,50 ± 1,36	6,06 ± 1,31	6,19 ± 1,37	5,91 ± 1,55	6,18 ± 1,13	5,97 ± 1,33	5,94 ± 1,27
Number of repeated pronouns (sum)	8	8	5	5	4	3	1	3
Number of creferences (sum)	29	30	33	33	34	28	27	32
Number of repeated lemmas (sum)	9	11	11	8	9	8	8	9

4.2.3 Experimental procedure

Data collection was carried out at the Brain Language Laboratory at the Freie Universität Berlin. Subjects were invited to sit in a sound-proof cabin, facing a computer monitor. They were instructed to read all question-reply pairs that would be displayed on the screen and to rate them. The ratings were prompted by the questions reported in Table 4.4 and were given on a 7-points Likert scale with the respective anchor labels written below the extreme values (1 and 7) and – when applicable – the middle (4) of the scale. Subjects were encouraged to provide intuitive ratings and to use the whole range of the scales. The written stimuli were visually presented using PsychoPy 2 (Peirce et al., 2019) in five distinct blocks. In each block, subjects had to rate all question-reply pairs under one of the following aspects or dimensions on a scale: (Function, FUN-R) the affirmative's function as a positive "yes" or negative "no" reply, (Coherence, COH-R) the coherence between the utterances performed by using the two sentences of the pair, (Directness, DIR-R) the directness of the utterances performed with the second sentence, (Predictability, PRE-R) predictability of the second utterance in context of the first, (Semantic Similarity, SSI-R) semantic similarity between the two utterances. Additionally, the certainty (CER-R) of the attribution of the reply to a "yes"/"no" function was derived from the Function rating and corresponded to the distance between the Function rating and the middle of the Function scale. In order to avoid response biases due to the exact wording of the rating questions, the rating questions 3 to 5 were available in two versions, one for each half of the subjects ("How in/direct ... ?"; "How un/predictable ... ?"; "How close/distant ... ?"). For the same reasons, the anchor labels of the Likert scales were mirrored for half of the subjects. Question wording and anchor labels layout were however both kept constant across blocks within subjects. The order of the blocks (and so the order in which each subject gave the individual ratings) was randomised across participants.

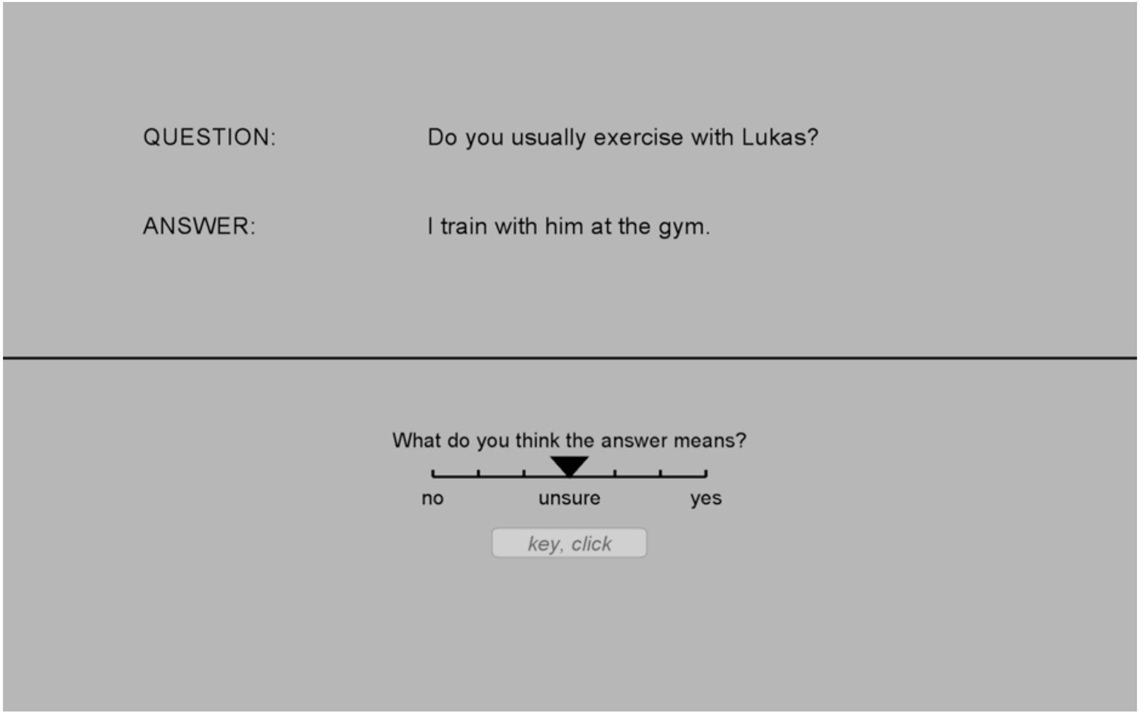
All stimuli (direct and indirect from both sets) were displayed in random order within each block and with different randomizations for each subject. Each subject was exposed to all stimuli (both the direct and indirect versions) such that every item was rated 28 times and such that every subject saw each stimuli version (direct vs. indirect) five times. For each trial, the question and the reply were shown simultaneously on separate lines in the upper half of the screen. At the same time, the question prompting the rating and the rating scale itself were displayed on the lower part of the screen. Subjects had to select one of the discrete Likert scale values with the left and right arrow keys and confirm with the return key (Figure 4.1). Each screen was shown until a selection was confirmed and the next screen including a new sentence pair was shown immediately. Overall, the ratings took

Table 4.4: Questions used to prompt the rating of each of the measured dimensions, together with their respective anchors. Note that the Certainty dimension was not rated directly by the subject, but derived from the Function ratings, and is therefore not shown in this table.

Rating	**Question prompting rating**	**Lower anchor**	**Middle anchor**	**Upper anchor**
FUNCTION (FUN-R)	What do you think the answer means?	No	unsure	yes
COHERENCE (COH-R)	How well do you think the question was answered?	not well at all	-	very well
DIRECTNESS (DIR-R)	How direct/indirect was the answer?	not direct at all / not indirect at all	-	very direct / very indirect
PREDICTABILITY (PRE-R)	How predictable/unpredictable was the answer?	not predictable at all / not unpredictable at all	-	very predictable / very unpredictable
SEMANTIC SIMILARITY (SSI-R)	How close/distant was the meaning of question and answer?	not close at all / not distant at all	-	very close / very distant

ca. 2 h. Short breaks were allowed in the middle and at the end of each block (i.e. about every 10–15 min). In addition, subjects were asked to leave the testing cabin and take a longer (15 min) break after the end of the third block.

Figure 4.1: Example of experimental procedure. The stimulus to rate is presented on the upper part of the screen (interrogative and affirmative simultaneously). In the lower part of the screen, the rating question and the Likert-scale are depicted. Subjects can select their ratings using the arrow keys and confirm it with the return key.



QUESTION: Do you usually exercise with Lukas?

ANSWER: I train with him at the gym.

What do you think the answer means?

4.2.4 Analysis

Data preprocessing and statistical analyses were per-formed in Matlab 2014b (The MathWorks Inc., Natick, MA, 2000), R 3.6.1 (RC-Team, 2019) and SPSS Statistics 26 (IBM, Armonk, NY).

First, all ratings where the anchor labels of the Likert scale were presented in a mirrored fashion (see Section above) were inverted such that they matched the ratings that had non-mirrored anchor labels. Values produced during the Function rating were transformed to produce an additional variable, namely Certainty (CER-R), which was the rectified distance of the interpretation rating from the centre of the scale (range 0–3). For comparability with the other scales which started from 1, we added the value 1 to the rectified values. Therefore, our final Certainty scale ranged from a minimum score of 1 to a maximum score of 4, which captured how close function ratings were to the "yes" or "no" extremes. For instance, a Function rating of 1 or of 7 corresponded to a Certainty of 4, while a Function rating of 4 corresponded to a Certainty rating of 1. Thus, the following dimensions were available for statistical analysis: certainty (CER-R) about the correctness of yes/no responses, coherence (COH-R) between question and reply, directness of the reply (DIR-R), predictability of the reply (PRE-R), and semantic similarity between question and reply (SSI-R). The dimensions of Function (FUN-R) were only used for item rejection purposes, as explained below.

Next, direct-indirect item pairs were excluded from all analyses if, based on the average rating over all partaking subjects, (1) the sentence pair of the "direct" group was judged by the experimental subjects to be more indirect as compared with the "indirect" one (SA-matched set: 3 pairs; non-SA-matched set: 5 pairs); and/or (2) one of the two stimuli was not predominantly assigned to the expected function by the participants, meaning that "no" items were rejected if average FUN-R > 3.5 and "yes" items were rejected if average FUN-R < 4.5 (SA-matched set: 1 pair, non-SA-matched set: 7 pair). This led to the exclusion of 16 direct-indirect stimuli pairs across sets (SA-matched set: 4 items, namely 5.3%; non-SA-matched set: 12 items, namely 15.8%). As an unequal amount of "yes" and "no" pairs were excluded within each set, an additional 4 pairs were removed across sets such that, in both SA-matched and non-SA-matched sets, an equal number of "yes" and "no" pairs were maintained (SA-matched set: 2, non-SA-matched set: 2). These latter pairs were selected so as to balance the remaining items of each set. The final analysis included 70 item pairs in the SA-matched set (6 overall exclusions, namely 7.9%) and 62 in the non-SA-matched set (14 overall exclusions, namely 18.4%), with an equal amount of "yes" and "no" pairs within each Set (see Table 4.1).

Linear mixed models analysis

Our *a priori* hypotheses concerning differences in measured propertied between direct and indirect replies and the effect of speech act-matching (see Section 4.1, "Introduction") were tested using linear mixed models (LMM) from the R package *lme4* (Bates et al., 2015). The models all included a random intercept for both subject and item, which accounted for inter-subject and inter-item variability, respectively. The present study includes three independent variables: In/Directness [Direct, Indirect], Speech Act (SA) matching [SA-matched, non-SA-matched] and Polarity [yes, no]. For each rating, we started building a null model, which did not contain any fixed effects. Subsequently we progressively increased the complexity of the model by adding the various factors alone or in interaction. All models were based on the default contrast of *lme4* package (the so-called "treatment" contrast) and for each predictor the base level was: "direct" for In/Directness, "SA-matched" for SA-matching and "no" for Polarity. For each increase in complexity, the model was compared with the previous one in a pairwise fashion using a likelihood ratio test (LRT).

(null) RATING ∼ 1 + (1|Subject) + (1|Item)
(1) RATING ∼ In/Directness + (1|Subject) + (1|Item)
(2) RATING ∼ In/Directness + SA-matching + (1|Subject) + (1|Item)
(3) RATING ∼ In/Directness * SA-matching + (1|Subject) + (1|Item)
(4) RATING ∼ In/Directness + Polarity + (1|Subject) + (1|Item)
(5) RATING ∼ In/Directness * Polarity + (1|Subject) + (1|Item)
(6) RATING ∼ In/Directness + Polarity + SA-matching + (1|Subject) + (1|Item)
(7) RATING ∼ In/Directness * Polarity * SA-matching + (1|Subject) + (1|Item)

The residuals were visually inspected for normality, equivariance and independence. For each rating, post-hoc tests were performed on the basis of the best fitting model. For this, we used the function *emmeans()* from the package *emmeans* (https://cran.r-project.org/web/packages/emmeans/index.html) and applied Tuckey's Honest Significant Difference (HSD) to correct for multiple comparisons.

Correlations between dimensions

If indirectness comes with differences in Predictability, Certainty, Semantic Similarity and Coherence with its linguistic context, it is possible that these dimensions also correlated with one another. To test the hypothesis of linear relationships between the outcomes of the ratings, pairwise Pearson correlations between the average rating values by item were performed in the two sets collapsed. Collapsing of data across sets was motivated by statistical results of the Linear Mixed Models analysis reported below. Correlation analyses were performed on all rating dimensions except Function, which was omitted as visual inspection indicated that the respective ratings did not show a normal distribution but a bimodal one. This was an unsurprising consequence of the fact that the replies were always interpretable as “yes” or “no”, pushing the subjects to provide ratings that tended to be clustered at the extremes of the Function scale. Note however, that, after the data transformation into the new variable Certainty, which we explained below, the functional data could still be used. The statistical evaluation of the correlations was Bonferroni corrected (for 10 comparisons). We therefore report corrected p values.

Principal component analysis

A principal component analysis (PCA) was performed in an exploratory analysis to further quantify the relationship between the various ratings. The PCA allows to determine whether the variability captured by our five ratings is better captured by a number of underlying variables. In particular, it allowed to investigate whether our original dimensions tended to all load (i.e. to be assimilated) onto the same underlying component or whether they segregated on different ones. In other words, it allows to check how interconnected these dimensions are. Before proceeding, the

Kaiser-Meyer-Olkin measure of sampling adequacy (KMO), the Barlett's Test of Sphericity and the correlation matrix determinant were conducted in order to ensure that our data met the assumptions of PCA (Field, 2000). Next, the average values for Coherence, Directness, Predictability, Semantic Similarity and Certainty for items of both sets collapsed (264 items) were entered in the PCA (5 rated properties x 264 items matrix). The number of components to be extracted in the PCA was defined using the Kaiser criterion and the varimax rotation was applied in order to achieve orthogonality between components.

4.3 Results

4.3.1 Ratings across (in)directness, SA-matching and polarity

For each of the ratings, the outputs of all the individual comparisons in the linear-mixed models analysis are shown in Table 4.5 together with the corresponding statistical parameters. As our hypothesis for the rated dimensions of interest might be considered related to one another, the table also provides the significance criterion after correction for multiple comparisons (Bonferroni, 5 comparisons). All best models remain significant after correction for multiple comparisons. To further investigate these two-and three-way interactions, we proceeded to post-hoc tests with Tukey's HSD correction for multiple comparisons to identify where these differences occurred. For conciseness, we report in text only significant differences in single-degree-of-difference pairwise comparisons. A full report of all post-hoc pairwise comparison can be found in Appendix C.2 (see Tables C.2-C.6). Additionally, an indication of the inter-rater reliability is provided by the mean standard deviation of each item, separated by SA-matching, Directness and Polarity, reported in Appendix C.1.

Linear mixed models analysis indicated that all the ratings were explained by a significant main effect of the In/Directness condition alone (DIR-R: $\chi^2(1) = 3241.8$, $p < 0.001$, CER-R: $\chi^2(1) = 1106.9$, $p < 0.001$; COH-R: $\chi^2(1) = 3183.5$, $p < 0.001$, PRE-R: $\chi^2(1) = 1119.6$, $p < 0.001$, SSI-R: $\chi^2(1) = 2414.3$, $p < 0.001$, see Table 4.5) indicating that in general indirect replies received lower ratings compared to direct replies. Importantly, the fact that the Directness rating was reflected by the In/Directness factor confirms the classification of speech acts into the direct and indirect categories, which had been performed during stimulus preparation according to established linguistic criteria.

However, testing further models allowing for interactions with the factors of Polarity and SA-matching indicated that some interaction effects were detectable for all variables and were better at accounting for the data than a main effect of the In/Directness condition (see Table 4.5 and Figure 4.2). In fact, the Certainty rating was best explained by a two-way interaction between the factors In/Directness and Polarity (CER-R: $\chi^2(1) = 42.6$, $p < 0.001$, see Table 4.5) meaning that the difference in these ratings between direct and indirect replies was modulated by whether the reply was intended as "yes" or as a "no". Direct items were characterised by significantly higher Certainty ratings than the indirect ones both in the "no" ($p < 0.001$) and "yes" ($p < 0.001$) Polarity condition. However, while direct items received similar ratings regardless of their interpretation as "yes" or "no" ($p = 0.703$), indirect ratings were judged as having a slightly higher Certainty when conveying a no rather than a yes ($p < 0.001$).

Most importantly, the ratings of Directness, Coherence, Predictability and Semantic Similarity were all best explained by a three-way interaction between the factors In/Directness, SA-matching and Polarity (DIR-R: $\chi^2(4) = 22.9$, $p < 0.001$; COH-R: $\chi^2(4) = 53.2$, $p < 0.001$; PRE-R: $\chi^2(4) = 46.2$, $p < 0.001$; SSI-R: $\chi^2(4) = 16.9$; see Table 4.5) indicating that all cognitive ratings obtained were modulated by all three factors in a complex manner. Note that none of the ratings was explained by an interaction between Directness and SA-matching alone. Consistent with the main prediction, Directness, Coherence, Predictability and Semantic Similarity ratings were significantly lower for indirect than for direct items, irrespective of Polarity or SA-matching. Thus, indirect replies received lower ratings than direct items across all SA-matching by Polarity combinations ($p < 0.001$). While this difference underlies the main effect of the Directness factor, the complex 3-way interactions were due to the following modulation: indirect replies with positive polarity were rated lower than the corresponding negative polarity items, but this effect was only significant for non-SA-matched materials ($p < 0.001$). Recall that in the non-SA-set, indirect "yes" replies performed an acceptance of an offer (e.g., "Shall we go to the cinema?" being responded to by saying "There is an interesting new movie.") while the "no" indirect replies performed a declination of an offer/invitations (e.g., "Shall I buy the tickets?" being responded to by saying "We haven't decided on a destination yet."). Interestingly, in the non-SA-matched set, the items calling for a "yes" answer were not only rated lower compared with their corresponding "no"-items, but, also compared to their negative SA-matched counterparts on almost all scales tested, including Directness, Predictability and Coherence ratings (DIR-R: $p = 0.009$; COH-R: $p = 0.003$; PRE-R: $p = 0.034$). For Semantic Similarity, there was a numerical difference of average values pointing in this same direction, which was however not significant (SSI-R: $p = 0.374$).

Table 4.5: For each of the ratings of certainty (CER-R), coherence with the question (COH-R), directness (DIR-R), predictability (PRE-R) and semantic similarity to the question (SSI-R), the table provides information about the tested models, namely the Bayesian Information Criterion (BIC), the Akaike Information Criterion (AIC), and the log-likelihood (logLik). For each tested model, the fixed structure is reported in abbreviated form (IND: In/Directness; SAM: SA-matching; POL: Polarity). For each rating, the model that best predicted the data is indicated in bold. The p-values are reported uncorrected for multiple comparisons. Note that all winning models survive Bonferroni correction for 5 comparisons (corrected $p_{critical} = 0.01$). All models had the same random structure (see Section 4.2, "Materials and Methods").

Variable	**Model**	**Df**	**AIC**	**BIC**	**logLik**	**deviance**	**Chisq**	**Chi Df**	***p***	**Preferred Model**
DIR-R	(null)	4	31430	31458	-15711	31422	-	-	-	-
	(1) IND	5	28190	28225	-14090	28180	3241.8	1	<0.001***	1
	(2) IND + SAM	6	28193	28235	-14091	28181	0	1	1	1
	(3) IND * SAM	7	28198	28247	-14092	28184	0	2	1	1
	(4) IND + POL	6	28194	28236	-14091	28182	0	1	1	1
	(5) IND * POL	7	28118	28167	-14052	28104	76.169	2	<0.001***	5
	(6) IND + SAM + POL	8	28121	28177	-14052	28105	0	1	1	5
	(7) IND * SAM * POL	**11**	**28103**	**28180**	**-14040**	**28081**	**22.889**	**4**	**<0.001*** **	**7**
COH-R	(null)	4	30501	30529	-15246	30493	-	-	-	-
	(1) IND	5	27319	27354	-13655	27309	3183.5	1	<0.001***	1
	(2) IND + SAM	6	27322	27364	-13655	27310	0	1	1	1
	(3) IND * SAM	7	27328	27377	-13657	27314	0	2	1	1
	(4) IND + POL	6	27317	27359	-13652	27305	4.2656	1	0.039*	4
	(5) IND * POL	7	27224	27272	-13605	27210	95.113	1	<0.001***	5
	(6) IND + SAM + POL	8	27227	27283	-13606	27211	0	1	1	5
	(7) IND * SAM * POL	**11**	**27179**	**27255**	**-13578**	**27157**	**53.227**	**4**	**<0.001*** **	**7**
PRE-R	(null)	4	29609	29637	-14800	29601	-	-	-	-
	(1) IND	5	28492	28526	-14241	28482	1119.6	1	<0.001***	1
	(2) IND + SAM	6	28496	28537	-14242	28484	0	1	1	1
	(3) IND * SAM	7	28497	28546	-14242	28483	0	2	1	1
	(4) IND + POL	6	28491	28533	-14240	28479	2.2658	1	0.1323	1
	(5) IND * POL	7	28388	28436	-14187	28374	108	2	<0.001***	5
	(6) IND + SAM + POL	8	28392	28447	-14188	28376	0	1	1	5
	(7) IND * SAM * POL	**11**	**28349**	**28426**	**-14164**	**28327**	**46.167**	**4**	**<0.001*** **	**7**
SSI-R	(null)	4	30153	30181	-15072	30145	-	-	-	-
	(1) IND	5	27741	27776	-13865	27731	2414.3	1	<0.001***	1
	(2) IND + SAM	6	27746	27787	-13867	27734	0	1	1	1
	(3) IND * SAM	7	27749	27797	-13867	27735	0	2	1	1
	(4) IND + POL	6	27745	27787	-13866	27733	0	1	1	1
	(5) IND * POL	7	27649	27698	-13818	27635	95.484	2	<0.001***	5
	(6) IND + SAM + POL	8	27654	27710	-13819	27638	0	1	1	5
	(7) IND * SAM * POL	**11**	**27640**	**27717**	**-13809**	**27618**	**16.904**	**4**	**0.002** **	**7**
CER-R	(null)	4	18828	18856	-9410	18820	-	-	-	-
	(1) IND	5	17723	17758	-8856.5	17713	1106.9	1	<0.001***	1
	(2) IND + SAM	6	17729	17771	-8858.6	17717	0	1	1	1
	(3) IND * SAM	7	17731	17780	-8858.7	17717	0	2	1	1
	(4) IND + POL	6	17721	17763	-8854.6	17709	3.9103	1	0.048*	4
	(5) IND * POL	**7**	**17681**	**17729**	**-8833.3**	**17667**	**42.571**	**1**	**<0.001*** **	**5**
	(6) IND + SAM + POL	8	17687	17742	-8835.4	17671	0	1	1	5
	(7) IND * SAM * POL	11	17689	17765	-8833.4	17667	0	4	1	5

Figure 4.2: Average ratings for the various dimensions: (A) Directness (DIR-R), (B) Coherence with the question (COH-R), (C) Predictability (PRE-R), (D) Semantic Similarity to the Question (SSI-R), (E) Certainty (CER-R), (F) Function (FUN-R). Each of these are further divided by In/Directness (direct, indirect), SA-matching (SA-matched, non-SA-matched) and Polarity of the answer (yes, no). Error bars indicate the standard error of the mean based on single trial data.

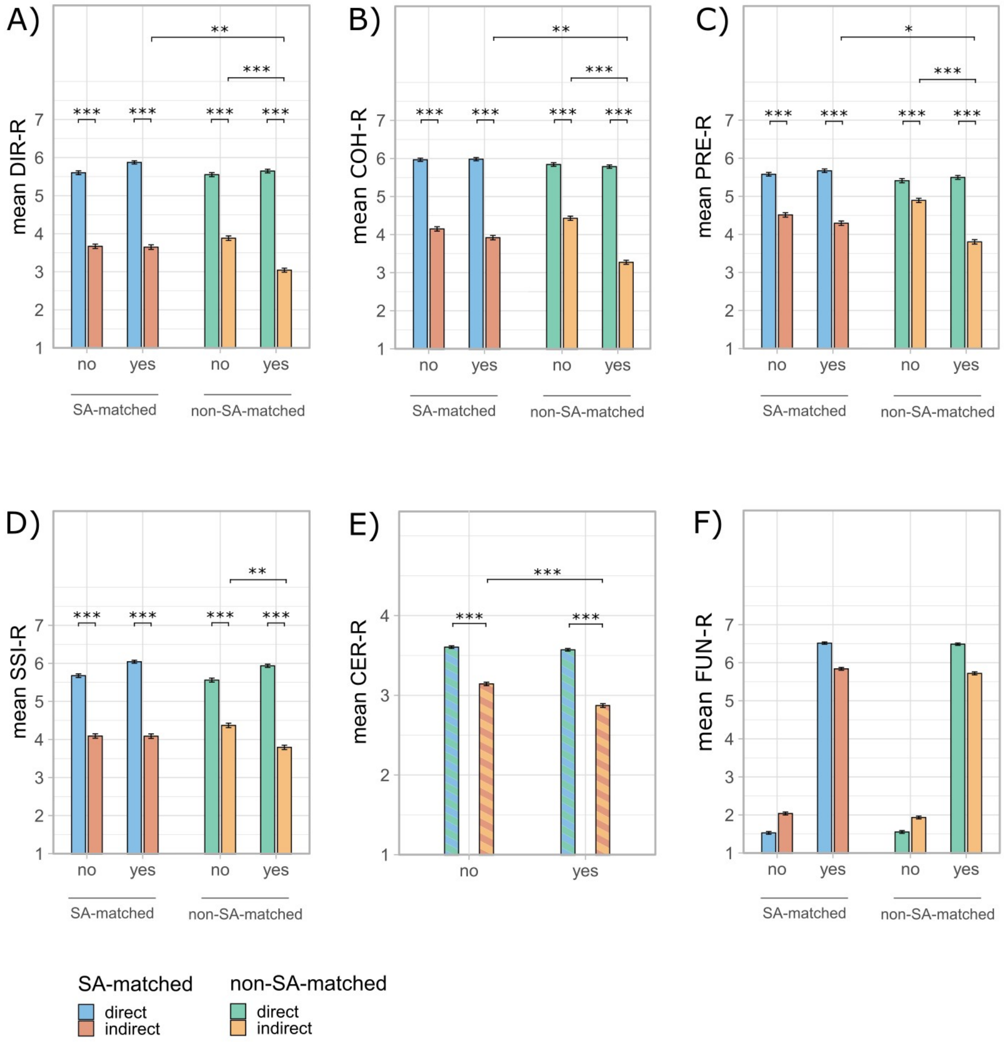


Table 4.6: Summary of the fixed and random effects of the best fitting model for each of the collected ratings of certainty (CER-R), coherence (COH-R), directness (DIR-R), predictability (PRE-R) and semantic similarity to the question (SSI-R). Default "treatment" contrasts were used, such that the base level for In/Directness, Polarity and SA-matching were "direct", "no" and "SA-matched" respectively.

	FIXED EFFECTS				**RANDOM EFFECTS**		
	Effect	*β*	SEM	t-value	Effect	Variance	SD
DIR-R	Intercept (direct, no, SA-matched)	5.53	0.15	36.16	Intercept (by item)	0.41	0.64
	In/Directness (indirect)	-1.94	0.06	-30.10	Intercept (by subject)	0.28	0.53
	Polarity (yes)	0.34	0.16	2.07	Residual	2.09	1.45
	SA-matching (matched)	0.02	0.17	0.10			
	In/Directness (indirect) : Polarity (yes)	-0.29	0.09	-3.16			
	In/Directness (indirect) : SA-matching (non matched)	0.27	0.09	2.87			
	Polarity (yes) : SA-matching (non matched)	-0.24	0.24	-1.03			
	In/Directness (indirect) : Polarity (yes) : SA-matching (non matched)	-0.65	0.13	-4.92			
COH-R	Intercept (direct, no, SA-matched)	5.91	0.14	40.82	Intercept (by item)	0.40	0.63
	In/Directness (indirect)	-1.88	0.06	-31.07	Intercept (by subject)	0.23	0.48
	Polarity (yes)	0.07	0.16	0.44	Residual	1.85	1.36
	SA-matching (matched)	-0.07	0.16	-0.42			
	In/Directness (indirect) : Polarity (yes)	-0.18	0.09	-2.10			
	In/Directness (indirect) : SA-matching (non matched)	0.47	0.09	5.35			
	Polarity (yes) : SA-matching (non matched)	-0.13	0.23	-0.55			
	In/Directness (indirect) : Polarity (yes) : SA-matching (non matched)	-0.92	0.12	-7.42			
PRE-R	Intercept (direct, no, SA-matched)	5.53	0.15	36.11	Intercept (by item)	0.33	0.58
	In/Directness (indirect)	-1.11	0.07	-16.88	Intercept (by subject)	0.34	0.58
	Polarity (yes)	0.15	0.15	0.97	Residual	2.16	1.47
	SA-matching (matched)	-0.11	0.15	-0.74			
	In/Directness (indirect) : Polarity (yes)	-0.27	0.09	-2.94			
	In/Directness (indirect) : SA-matching (non matched)	0.59	0.09	6.20			
	Polarity (yes) : SA-matching (non matched)	-0.06	0.22	-0.28			
	In/Directness (indirect) : Polarity (yes) : SA-matching (non matched)	-0.90	0.13	-6.74			
SSI-R	Intercept (direct, no, SA-matched)	5.61	0.15	36.51	Intercept (by item)	0.25	0.50
	In/Directness (indirect)	-1.59	0.06	-25.37	Intercept (by subject)	0.41	0.64
	Polarity (yes)	0.43	0.13	3.24	Residual	1.98	1.41
	SA-matching (matched)	-0.05	0.14	-0.36			
	In/Directness (indirect) : Polarity (yes)	-0.37	0.09	-4.14			
	In/Directness (indirect) : SA-matching (non matched)	0.40	0.09	4.40			
	Polarity (yes) : SA-matching (non matched)	-0.06	0.19	-0.30			
	In/Directness (indirect) : Polarity (yes) : SA-matching (non matched)	-0.59	0.13	-4.57			
CER-R	Intercept (direct, no)	3.60	0.08	44.15	Intercept (by item)	0.07	0.27
	In/Directness (indirect)	-0.47	0.02	-19.68	Intercept (by subject)	0.15	0.39
	Polarity (yes)	-0.02	0.05	-0.47	Residual	0.54	0.74
	In/Directness (indirect) : Polarity (yes)	-0.23	0.03	-6.90		0.09	0.30

4.3.2 Relationship between dimensions

Correlations between dimensions

To examine a possible link between the five main dependent variables, we ran Pearson correlations between all pairwise combinations. Function (FUN-R) in its raw form was excluded, but was included in its transformed form, namely the Certainty ratings (CER-R). All pairwise correlations were significant (all $p > 0.001$) after Bonferroni correction for multiple comparisons (for 10 comparisons) and overall confirmed a strong positive linear association between all of them, with Pearson's R coefficients all greater than 0.80 (Figure 4.3). Thus, whenever an item received low (high) ratings on one scale, it was very likely that it also received low (high) ratings on the other scales. These results clearly document a strong correlative link between the measures.

Principal component analysis

To examine whether, in face of the documented strong correlations, any of the five dimensions could be dissociated from the others, principal component analysis was performed. Ratings of Certainty, Coherence, Directness, Predictability and Semantic Similarity to Context Question were entered into one analysis. The sampling adequacy was confirmed by a Kaiser-Meyer-Olkin (KMO) of 0.883. Conceptually, the KMO indicates the ratio between the variance that is shared between the variables and the one that is not shared. It can vary between 0 and 1 and a value larger than 0.8 is considered appropriate for PCA and indicates that "the pattern of correlations is relatively compact" (Field, 2000). Correlations between input variables in our dataset were large enough as confirmed by Barlett's Test of Sphericity ($\chi^2(10) = 2395.460$, $p < 0.001$). Yet the variables were not collinear, as indicated by a determinant of 0.00015. Therefore, our dataset met the assumptions for reliable PCA (Field, 2000, pp. 683-686). Of the five resulting principal components, principal component 1 (PC1) had an Eigenvalue of 4.59 and by itself explained 91.86% of the variance in the data. All further dimensions had Eigenvalues below 0.3 (see Table 4.7, panel A and Figure 4.4), thus not passing the Kaiser criterion of Eigenvalue of 1 (Kaiser, 1960). Additionally, all original dimensions loaded similarly onto PC1, with rotated factor loadings above 0.9 (Table 4.7, panel B). Thus, one single principal component (PC1) seemed to explain most of the variance in our set of items.

Figure 4.3: Correlation matrix shown for the following rated dimensions: certainty (CER-R), coherence with the question (COH-R), directness (DIR-R), predictability (PRE-R) and semantic similarity to the question (SSI-R). The plots below the diagonal show the scatter plot displaying the relationship between pairs of variables, together with the regression line in red. Each observation represents an item and its average score on a given scale. The plots above the diagonal show the respective Pearson correlation coefficient (R) and significance level after correction for multiple comparisons (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

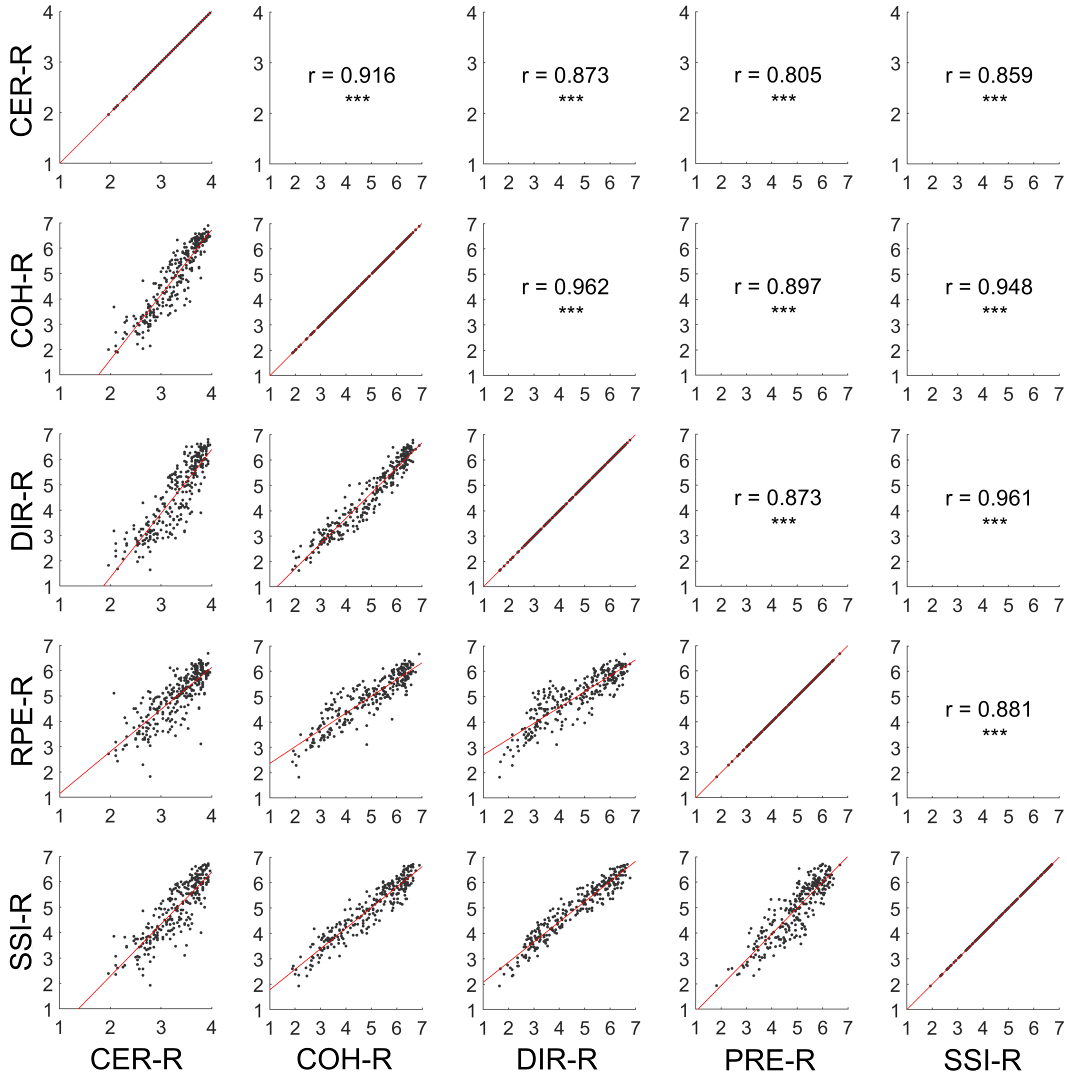


Figure 4.4: Scree plot depicting the Eigenvalues of each principal component identified by principal component analysis (PCA), together with the respective percentage of explained variance. The red dotted line represents Kaiser's criterion at Eigenvalue 1.

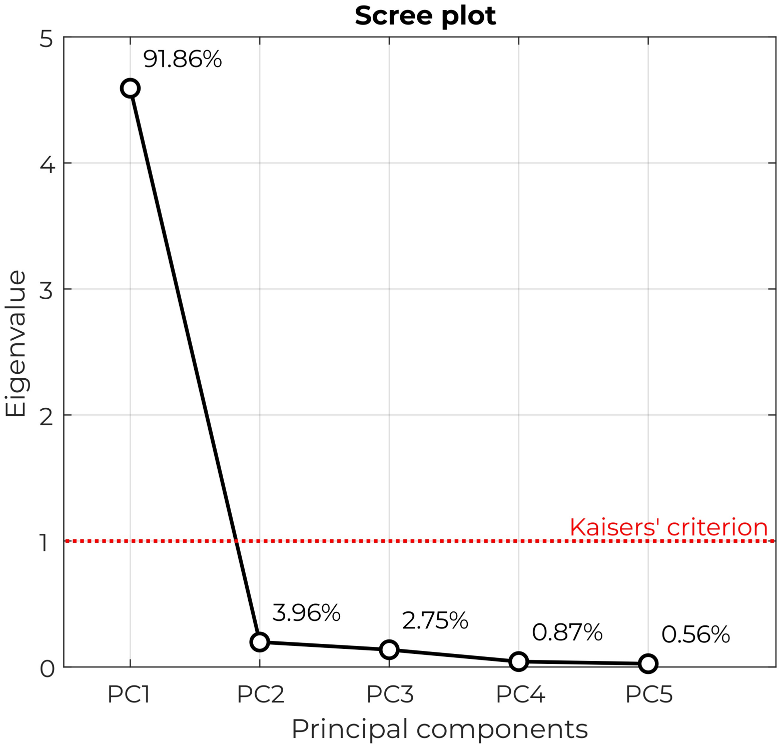


Table 4.7: (A) Output of the principal component analysis specifying Eigenvalues, percentage of explained variance and cumulative percentage of explained variance for each extracted principal component. (B) The rotated component matrix indicating the factor loads for PC1. PC2 is reported too for reference.

A) Intitial Eigenvalues

Component	Total	%of Variance	Cumulative %
PC1	4.593	91.864	91.864
PC2	0.198	3.957	95.821
PC3	0.137	2.750	98.570
PC4	0.043	0.869	99.439
PC5	0.028	0.561	100.000

B) Rotated Component Matrix

Original dimension	PC1	PC2
COH	-0.986	-0.036
DIR	-0.975	0.013
PRE	-0.930	0.291
SSI	-0.971	0.059
CER	-0.929	-0.329

4.4 Discussion

In the present study, we asked whether linguistic indirectness (In/Directness factor) of speech act sequences expressed by two consecutive sentences is systematically associated with other cognitive variables, including the interpretative Certainty and Predictability of the second speech act and the Coherence and Semantic Similarity between the sentences used. Furthermore, we assessed whether any such association was modulated based on whether indirectness co-occurred with a speech act change (SA-matching factor) and whether the reply was intended to be understood as a "yes" or a "no" response (Polarity factor). Importantly we also asked whether these cognitive properties of direct and indirect speech acts were interlinked with one another.

As expected, subjects consistently found the indirect replies to be less direct than the direct ones, but they also judged the corresponding interpretation to be less certain, less coherent with respect to the context question, and less predictable and less semantically similar to the context question. Complex three-way interactions of the factors In/Directness (direct/indirect), Polarity (yes/no) and SA-matching (SA-matched/non-SA-matched) were seen for the Directness ratings, and for those of Coherence, Predictability and Semantic Similarity. These interactions were due to significant differences between the cognitive ratings of replies meant to express "yes" and "no"-responses in the non-SA-matched set, but not in the SA-matched set. Note that in the non-SA-set, indirect replies came together with a change of speech act function relative to their direct control: "yes" replies performed an acceptance of an offer (e.g., "Shall we go to the cinema?" being responded to by saying "There is an interesting new movie.") while the "no" indirect replies performed a declination of an offer/invitations (e.g., "Shall I buy the tickets?" being responded to by saying "We haven't decided on a destination yet."). Conversely, in the SA-matched set, no speech act function change occurred, relative to the direct control: "yes" replies performed a confirmation (e.g., "Are you bringing your cat to the vet?" being responded to by saying "It got wounded.") while "no" replies preformed a disconfirmation (e.g., "Did you have time for sightseeing?" being responded to by saying "It was a business trip."). Thus, in the non-SA-matched set, for all four rating variables, there were relatively reduced values of the "yes" responses relative to the "no"replies, and relative to their SA-matched "yes" response counterparts, although the latter effect reached significance for only three of the four rating dimensions (not for Semantic Similarity). In other words, for some of the stimuli (positive polarity items), lack of speech act matching led to an increase of the ratings of the cognitive differences between direct and indirect speech acts. Furthermore, indirect replies – but not direct ones – had a more certain interpretation in case they conveyed a “no” compared to when they conveyed a “yes”. Crucially, all ratings displayed strong positive and significant correlations with each other. This finding was further supported by the fact that principal component analysis (PCA) yielded one single major component explaining ca 92% of the variance, onto which all our rating dimensions loaded about equally, thus speaking for these ratings being all indices of one single underlying property. Furthermore, a supplementary analysis showed that the difference between direct and indirect item pairs in any given rating correlated with the differences in all other ratings (see Appendix C.3). Finally in an item-by-item inspection, only a very small subset of direct-indirect item pairs could be identified, where the direct and indirect items were matched for the above-mentioned properties, while still differing in their directness rating (see Appendix C.3).

The present study thus demonstrated that significant differences could be found in the perceived cognitive properties of direct and indirect speech acts, even when these were conveyed by the same linguistic form and when their relationship with their linguistic context was matched in terms of various psycholinguistic variables. Indirectness of speech acts never stands alone, but almost always is tied to differences in interpretative Certainty, Predictability, Coherence and Semantic Similarity to the context. Furthermore, for some communicative activities, including those items in our sets that were interpretable as “yes” responses, the cognitive differences between indirect and direct speech acts appear to be particularly strong if these are not matched for communicative function. This latter observation shows that lack of speech act matching may artificially alter and enhance the cognitive differences linked with in/directness *per se*.

4.4.1 Properties of indirectness

The first and most important finding of the current study is that direct and indirect speech acts were all differing in the five dimensions examined, such that compared to direct replies, indirect replies were (1) perceived as less direct by the participants, (2) interpreted with less certainty, and considered as (3) less coherent with their context, (4) less predictable and (5) exhibiting less semantic similarity to their context. These rating dimensions, while being modulated by other factors too (SA-matching and Polarity, see Discussion section “Speech Act Type, Polarity and Politeness”) were most and foremost affected by the direct/indirect status of the critical utterance, as indicated by the estimates of the respective linear mixed models (see Table 4.6). Before moving on to discuss each property individually, we would like to address one potential confound which could have affected all ratings, namely that subjects were exposed multiple times to the same stimuli while progressing through the various rating blocks. It is therefore possible, that the degree of exposure to the stimuli affected the responses of the various subjects during the ratings. To evaluate this possibility, we performed additional analyses (see Appendix C.4) showing that the degree of exposure of the subject to the stimuli (i.e. the position of the block for a given rating in each subject's session) did not significantly affect the Coherence, Directness, Predictability and Semantic Similarity ratings. The only rating that was significantly affected was the Certainty of the interpretation. Indeed, the more subjects were exposed to the stimuli, the more certain they were in the interpretation of indirect replies, but not of the direct ones. Being exposed multiple times to the same indirect reply might have given more time to the subjects to think about an appropriate interpretation and to be certain of it. Exposure therefore had a significant facilitatory effect on the interpretation. This however does not contradict the result of our main analysis, but it reinforces it instead. Indeed, our main analysis still detected differences in Certainty between direct and indirect replies in spite of this difference being minimised by the degree of exposure to the indirect stimuli. To sum up, overall, there was no evidence suggesting that our subjects' ratings were affected by exposure on any of the dimensions. Only Certainty was slightly affected by exposure, but the general pattern of direct replies being interpreted with greater Certainty than indirect ones still remained.

Ratings of directness

First, the rating of the Directness of the stimuli indicated that, as we expected, indirect stimuli received lower directness rating than their direct counterparts. Although this finding may seem trivial on first view, it turns out to be important as it confirms that our stimulus choice was appropriate for investigating the phenomenon of linguistic indirectness. In other words, the *a priori* construction of direct and indirect stimuli according to well established linguistic criteria (see Material and methods) resonated with a more intuitive understanding of in/directness in lay subjects. In addition, note that indirect replies on average received ratings that were rather central on the Likert scale, which is consistent with the fact that indirectness, being commonly used in daily communication, is not perceived as an "extreme" phenomenon.

Ratings of predictability

Indirect replies were rated as significantly less predictable than direct ones. One may suggest that this observation may have been related to peculiarities of our study. One could criticise that, in our design, when the context question in the non-SA-matched set was understandable as an offer, the reply was always indirect. This could inadvertently have made subjects predict the indirect (vs. direct) reply and could therefore have biased the Predictability ratings toward relatively higher values. If Predictability ratings had indeed been affected, then both response options to an offer, i.e. *acceptance* and *declination*, would have achieved higher Predictability ratings compared to indirect replies in the SA-matched condition, where the direct/indirect status of the reply was not predictable. However, contrasting with the observed pattern, Predictability ratings of indirect *declinations* (non-SA-matched set) were in fact comparable to those of indirect *disconfirmation* (SA-matched set). Only the Predictability ratings for indirect *acceptance* (non-SA-matched set) received significantly lower cognitive ratings than for indirect *confirmations* (SA-matched set). This pattern of results is incompatible with the possibility that the difference between all indirect replies in the non-SA-matched set was caused by the contingency of an indirect reply following an offer. However, it still remains possible that, had the indirectness of the reply not been predictable by the *offer* in the context question, then indirect *declinations* and *acceptance* might potentially both have achieved lower Predictability scores than what they have. Importantly, the difference that we find between indirect *acceptance* and indirect *declination*, and that we interpret as a consequence of politeness dynamics (see below), cannot be explained by the fact that both were made more predictable by the preceding *offer*. We therefore consider the Predictability ratings not affected by the degree of exposure to the stimuli, nor by the fact that the indirectness of the reply in the non-SA-matched set was always anticipated by its context.

Grice proposed that human communication is based on a set of principles (or maxims) that people tend to tacitly take for granted during communication (Grice, 1975). Indirect speech acts are the result of the violation of the Relation maxim, stating that the speaker typically says things that are relevant to the ongoing discourse or situation. An expectation that a speaker follows the principle of Relevance might restrain the choices of utterances in their propositional content and consequently also in their form. For instance, if one asks, “Where are the scissors?” then the direct (and most immediately relevant) response to this query consists of mentioning a location by using a sentence similar to “The scissors/they are [location]”, e.g., “They are in Jim’s bedroom”. However, if the response is indirect, then it is possible to omit any information about the location of the scissors in the propositional content of the reply, e.g., “Jim used them for his arts & crafts project”. Note that in the indirect case, the reply significantly deviates from the expected direct reply in its propositional content and consequently also in its form (syntactically, lexically, phonologically, etc.). Indeed there are somewhat limited ways of communicating something directly, but multiple if not unlimited ways of communicating the same thing indirectly (Holtgraves, 1994, 1999). Therefore, we consider the lower predictability ratings associated with indirect replies to be the result of less constraints on their propositional content and form. It is of course still possible that certain ways of expressing something indirectly are more predictable than others (see Section 4.4.2, “Speech Act Type, Polarity and Politeness”) but based on the present data it appears that there is nevertheless a general and strong characteristic of indirectness, that it is less predictable than direct communication.

Ratings of semantic similarity and coherence relative to the context

In the present study, we cannot tell for sure to which extent the ratings measured the semantic similarity and coherence were affected by the indirectly conveyed message (so by the utterance at its non-literal level). However, the decreased coherence and semantic similarity relative to the context detected for indirect replies with respect to direct ones fits well with the Gricean framework, where indirect speech acts are defined as an apparent violation of the maxim of Relation (Grice, 1975; Levinson, 1983; Searle, 1979). Indeed, for an utterance to be considered unrelated to the ongoing discussion, this should be somehow thematically disconnected, namely semantically distant from the preceding linguistic context at the surface level, while a certain coherence is still achieved at a non-literal level, which should be fit well with the context and situation. Note in this respect that Semantic Similarity, Coherence and Directness where the three properties that most strongly correlated with one another (Figure 4.3), supporting the idea that these might be in a particularly close relationship. We therefore consider it most likely that the decreased semantic similarity and coherence that indirect replies have with their context is driven by differences at their literal level with their context and that they, together with predictability, are a direct consequence of the violation of the maxim of Relation. One may be inclined to state that indirectness, superficial coherence and semantic relationship are intrinsically connected. Our experimental study adds to this that is indeed very difficult to find example stimuli that dissociate the three cognitive features.

Ratings of Certainty of interpretation

Next comes Certainty of interpretation. Several researchers have pointed out that the implicature carried by a specific utterance is often associated with a degree of indeterminacy (Grice, 1975; Levinson, 1983). Holtgraves (1998) stresses how the same indirect speech act might allow for multiple implicatures to be derived, thus making indirectness typically ambiguous or vague, at least to a degree. For example, if Sarah replies “I am vegetarian” to the invitation “Are you coming to the steakhouse tonight?”, it is not quite certain which of these implicatures is the intended one (+>

I am not coming; +> I am coming but will not eat with you; +> I am showing you my appreciation by accepting this invitation to a steakhouse although I am vegetarian; +> I am morally judging you for eating habits that I do not endorse; etc.). Furthermore, one of the classic tests of implicatures is that, as opposed to literally conveyed meaning, they are cancellable or defeasible (Levinson, 1983), meaning that their implicated propositional content can be negated without causing a semantic contradiction. As a consequence, indirectness has often been considered to involve a lesser degree of commitment from the part of the speaker and to be "plausibly deniable" (Pinker et al., 2008; Reboul, 2017) or"off-record" (Brown & Levinson, 1987). Taking an experimental approach, Lee and Pinker (2010) compared the same "intended message" conveyed in more direct vs. more indirect manner. They found that subjects consider the message to be less certain, the more indirectly expressed it was. Additionally, Sternau et al. (2015) also compared to one another the same message when it was directly conveyed (bare linguistic meaning/explicature) vs. indirectly conveyed (strong/weak implicature). They found that, in the case of indirect speech acts, comprehenders were less confident about their truth judgement of the implicated content. Our present results are consistent with these previous studies and extend them by taking a different approach. Indeed, in these previous studies the approach taken was to keep the "intended message" constant and to vary the linguistic from to achieve different degrees of (in)directness. We here take the opposite approach and take the same linguistic form to be used either as a direct or indirect mean to convey different intended messages. Therefore, we here show that indirect speech acts are understood with less certainty also when the direct and indirect stimuli are conveyed by exactly the same sentence. A possible reason for this could be that the comprehender implicitly knows that the implicature could be defeated shortly thereafter during conversation, or potentially also at a later time point.

Relationship between properties

Strikingly, these dimensions were all strongly and positively inter-correlated (see Figure 4.3), a PCA could not separate the variability in our data into multiple underlying dimensions (see Figure 4.4). Instead, nearly all the variance in the ratings, including that in the directness ratings, was accounted for by one single component (PC1), which we could consider the directness-to-indirectness dimension. A further analysis (see Appendix C.3) also indicated that, whenever the direct and indirect replies within a pair scored differently on one scale, they most likely had equally distant scores on any other of the measured scaled. Further item-by-item examination indicated that only extremely few item pairs in our set escaped this pattern (see Appendix C.3, Table C.7 and C.8). These different analyses, all converge to the finding that the various properties of Predictability, Coherence with the context, Semantic Similarity to the context and Certainty of the interpretation are not easily separable from one another. Most likely, they all represent different facets of the phenomenon of indirectness. Note that, we of course do not claim that these various properties are the same thing as indirectness. Indeed, these properties can be realised by a linguistic stimulus without it being indirect. For instance, an utterance can be unpredictable without being indirect. However, our result seems to indicate that there is a solid relationship between indirectness and these properties, such that when an utterance is indirect, it seems not to be dissociable from being to a degree unpredictable, uncertain, dissimilar to the preceding linguistic context and incoherent. This link between properties is also consistent with the fact that differences at the level of individual properties are all tied to different linguistic explanations of indirectness (as discussed above) and can be seen as the direct cognitive manifestations thereof. So, altogether, it seems that the interrelated perceived (cognitive, psychological) properties that in the current study we found to systematically differ between direct and indirect replies are most likely inextricable from one another and are intrinsic to indirectness itself. Therefore overall, the characteristics of indirectness that have been identified by linguistic theorists are clearly reflected at the cognitive level in the mind of the comprehender.

4.4.2 Speech act type, Polarity and Politeness

The independent variable of in/directness of the reply most strongly affected the ratings across all measured dimensions. In addition, further factors modulated this central effect in a more fine-grained manner. The ratings of Certainty of interpretation were best explained by an interaction between the factors In/Directness and Polarity. In contrast, ratings of Directness, Coherence, Predictability and Semantic Similarity results were best explained by a three-way interaction between In/Directness, Polarity and SA-matching. The crucial difference behind this latter interaction can be described as follows: in the non-SA-matched set it was always the case that indirect replies conveying a “no” (namely *declining* an invitation/offer) achieved ratings that tended to be slightly more similar to their direct counterparts compared to those conveying a “yes” (namely *accepting* an invitation/offer). Interestingly, for the Certainty ratings, this pattern was also found in the SA-matched set. These effects are difficult to be attributed to the change of speech act type generally, as this should have affected all indirect replies co-occurring with a speech act change, irrelevant of whether they conveyed a “yes” or a “no”. It rather appears that for some speech acts, the change of speech act function had an effect of enhancing the directness/indirectness difference (“yes”-responses), whereas, for others, this effect was not significant. So how could this difference between "yes" and "no" indirect replies in the non-SA-matched set be explained? This motivates a closer look at the speech act changes realised in the non-SA-matched set.

We suggest that these findings can be interpreted in the framework of Politeness Theory (Brown & Levinson, 1987), according to which indirectness is one of the linguistic strategies that are typically used in natural conversation to mitigate face threatening acts (FTAs), which constitute an attack to the face of the hearer or of the speaker him/herself. In this context, the concept of face (Goffman, 1955) corresponds to the wish of each individual to be unimpeded (negative face) and to be desirable (positive face). In the present study, the non-SA-matched condition consisted of an interrogative-affirmative sentence pair, where the interrogative conveyed an *offer*, and the affirmative was understandable as an *acceptance* or *rejection* of the *offer*. Note that similar stimulus sets involving face-saving replies are common in neurocognitive research (see e.g. "Did you find my presentation convincing?"– "It's hard to give a good presentation" from Bašnáková et al., 2014; "Have you received any grants or scholarships during your studies?"–"The competition for scholarships in my field is extremely harsh.", from Bašnáková et al., 2015; "Will my film be successful at the box office?"– "It is hard for audiences to really enjoy a literary film." from Feng et al., 2021). More specifically, in our study *offers* included both proposals to engage in joint activities (henceforth *invitations*, such as "Shall we have some drinks?") and *offers* to do something for the other person (henceforth *offer of favour*, such as "Shall I do the dishes"?). In the framework of Politeness Theory, the case of an *invitation* made by A being *rejected* by B (negative polarity items) constitutes an FTA for A, as it threatens the positive face of A. Similarly, in the case of the *offer of favour* made by A, a *rejection* by B can potentially be a FTAs for A, because it would threaten A's positive face, whose good intention is being turned down. Note, that it is in principle possible that B accepting an *offer of favour* made by A also constitutes an FTA, albeit to A's negative face, as it will make A commit to actually doing the favour. Note however, in the present study, the o*ffers of favours* always consisted of rather trivial and small favours such that the subsequent *acceptance* (positive polarity) would most likely represent a minor degree of imposition on A. Thus, we consider that overall, in our set of stimuli, the "no" reply conveying a *rejection* would have been generally more face threatening than the "yes" reply conveying an *acceptance*. Therefore, in the indirect items of the non-SA-matched condition, the context question (*invitation* or *offer of favour*) opens the possibility for the subsequent reply to be an FTA. This was not the case for indirect items in the SA-matched condition, as these were mere descriptive *statement* of a state of affair, without face threatening potential. Furthermore, the speech act matching guaranteed that the type of speech act function was the same between direct and indirect conditions; the lack of such matching brings with it the danger of introducing additional differences. If – as Politeness Theory predicts – indirectness is frequent or more likely to occur when a face threatening message is being conveyed, then we would expect that there is greater motivation for the speaker to use and more reason for comprehenders to expect and thus process an indirect speech act when it is used to perform a face threatening act. This would be relevant for our negative polarity non-SA-matched indirect condition. Our present results fit well with this prediction as they indicate that the face-threatening indirect replies, i.e. the *invitation/offer declinations*, scored higher in all rated scales compared to non-face-threatening *invitation/offer acceptances*. Compared to indirect *acceptance*, indirect *declinations* seemed to be perceived in a way that was more similar to direct replies. This pattern of results suggests that these indirect *declinations* could be easier to process compared to indirect *acceptance*. Conversely, positive non-SA-matched indirect replies which were also not used to convey a FTA in their respective con-´texts (e.g., in response to an offer) appear to be perceived as relatively more anomalous than their SA-matched indirect counterparts on most cognitive dimensions, thus suggesting a greater indirectness effect for non-SA-matched items compared with matched ones if FTA issues are not relevant. In our proposed interpretation, it is the face-saving and politeness-related function of indirectness specifically in the negative-response condition that works against and minimises the otherwise present cognitive difference due to lack of speech act matching.

Our findings are in line with previous research reporting indications of interactions between the perception of indirect speech acts and the presence of a face threatening context. Indirect replies were found to be recognised as conveying indirect meaning more often and to be understood relatively more quickly when they occurred in a face threatening context (Holtgraves, 1991, 1998). Similar results were replicated in an eye-tracking study, where reading of indirect replies was found to be less fluent when their use was not justified by a face threat (Stewart et al., 2017). An unexpected result in our study, however, is that the Certainty of the interpretation was affected by an interaction between the factors Directness and Polarity also in the SA-matched conditions, which did not include FTAs. This latter effect is difficult to explain and we indeed do not have a fully convincing explanation to offer. One may argue that it may be a possibility, which once again rests in Politeness Theory, that there is a high co-occurrence between indirectly conveyed negative replies (replies that communicate a “no”) and face threatening contexts. Therefore, it could be that the mere fact that an indirect reply conveys a “no” biases the subject towards a reading the question-answer minimal dialogue as a face threatening scenario, also if it isn’t one. This in turn might have provoked “spill over” of these effects of Politeness on the SA-matched set, which actually did not involve a face threat. This possible explanation however remains highly speculative and further work might be needed to confirm this "spill-over" effect. To sum up, the present results are mostly in line with previous research establishing that indirect replies used to perform a face threatening speech act such as *rejecting* an *offer* are easier to process than indirect replies not performing an FTA. Additionally, they provide more insights with respect to what properties of the indirect replies are affected by that, namely certainty of interpretation, coherence relative to the question, directness, and predictability. Finally, they also demonstrate how a change of the type of speech act between direct and indirect conditions may overlay and confound the differences in cognitive properties normally present between direct and indirect speech acts *per se* (here: face threat, see Bašnáková et al., 2014). Contrasting with the pattern seen for the non-SA-matched set, the positive SA-matched replies, which were, according to our analysis, not overlaid by a confounding difference in face threat, showed more substantially reduced cognitive ratings for indirect relative to direct speech acts matched for their illocutionary function on most rating dimensions (Directness, Coherence, Predictability).

4.4.3 Implications for research on linguistic indirectness

After these results and conclusions, it appears that indirectness is a multifaceted phenomenon, as it comes together with a range of other factors. If indirectness is inextricably associated with lower predictability, lower coherence, lower certainty and lower semantic similarity, these properties are most likely each reflected by patterns of activity in the brain. The awareness of these properties should inform related psycholinguistic and neurolinguistic research and is of particular interest for the interpretation of neuroimaging studies. Indeed, studies investigating neural correlates of indirectness have relied on reverse inference (Poldrack, 2006) to interpret neuronal activation patterns. So, they explained the activation of certain brain regions by stating that they were involved in certain cognitive processes, but only assumed that these processes were required during comprehension of indirectness. With the present study, we provide evidence that there are several systematic differences in cognitive propertied between direct and indirect speech acts, thus providing a solid ground for interpretation of neuroimaging results and addressing the reverse inference problem.

fMRI studies conducted so far have isolated two main brain networks associated with processing of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2012; van Ackeren et al., 2016). First, the Theory of Mind network, including the temporo-parietal junction (TPJ), medial prefrontal cortex (mPFC) and precuneus (PreCun), which is hypothesised to contribute to the hearer taking the perspective of the speaker, or understanding what the speaker “really means”. Second, activation in regions belonging to the language network but extending also to the right hemisphere homologue areas, such as bilateral inferior frontal gyrus (IFG), bilateral middle temporal gyrus (MTG) and anterior temporal lobe (ATL) have been interpreted as reflecting semantic integration, semantic unification, and coherence building. The interpretation of these latter activation foci is congruent with our present result that, compared to direct replies, indirect ones are characterised by reduced Semantic Similarity and Coherence relative to the context. However, none of these regions that are typically activated during comprehension of indirectness has been interpreted in relation to lower Predictability or greater Uncertainty in the interpretation of indirectness. For instance, the above-mentioned studies consistently find a large portion of the mPFC to be active in response to indirect replies. mPFC is a multifunctional brain region has been found to be divided in multiple subregions based on the type of task that activate it (Amodio & Frith, 2006; De La Vega et al., 2016). Particularly, whereas the anterior part of the mPFC (arMFC as in Amodio and Frith, 2006; anterior portion of the mPFC as in De La Vega et al., 2016) was found to be associated with mentalizing, person perception, and social processing, the more dorsal part (prMFC as in Amodio and Frith, 2006; middle portion of the mPFC as in De La Vega et al., 2016) was associated with other cognitive functions such as “decision making” and processing of “uncertainty”. In several neuroimaging studies of indirectness, detected activation in the mPFC seems to overlap with the anterior, but also extend partially to the dorsal middle portion, which could possibly be a consequence of the higher degree of uncertainty in interpreting the “intended meaning”. Alternatively, or possibly in addition, this activation could reflect a greater involvement of prediction or prediction error processing in indirect speech act comprehension. Predictive processing has recently attracted substantial attention in the cognitive neurosciences (Friston, 2005; Wolpert & Kawato, 1998; Wolpert et al., 1995) and also in the psycho- and neurolinguistics field (Huettig, 2015; Pickering & Clark, 2014; Pulvermüller & Grisoni, 2020). Most studies exploring processing of predictable vs. unpredictable linguistic stimuli (which however did not constitute a semantic incongruency or syntactic violation) were based on EEG and MEG methods and have found larger N400 responses for less predictable words (Grisoni et al., 2021; Kutas & Hillyard, 1984; León-Cabrera et al., 2019; León-Cabrera et al., 2017; Van Berkum et al., 2005) and broad frontal anticipatory activity, so-called Prediction Potentials, before the onset of semantically predictable speech and written text (Grisoni et al., 2016; Grisoni et al., 2017; Grisoni, Moseley, et al., 2019; Grisoni et al., 2021; Pulvermüller & Grisoni, 2020). In view of the relatively reduced predictability of indirect replies (compared with direct ones) revealed by the present study, it could be expected that indirect replies elicit stronger N400 responses than direct ones as well as enlarged semantic prediction potentials elicited by critical words of the reply sentence. Unfortunately, to the best of our knowledge, only one study (Coulson & Lovett, 2010) investigated indirectness with EEG methods, a scarcity that is probably related to the methodological difficulties of such an enterprise. In particular in the case of indirect replies (typically sentences) it is difficult to create stimuli with a well-defined point in time when the indirectness of the speech act becomes effective, thus making it difficult to constrain the analysis of electrophysiological data with high temporal resolution to specific time windows. Coulson and Lovett (2010) examined the ERP responses while subjects read 7-word-sentences which could be understood as indirect *requests* or as direct *statements* depending on the preceding context. In their case, the context was not defined by the previous turn in dialogue, but by a brief text describing the situation. They found no differences between direct *statements* and indirect *requests* in the N400 responses for any of the individual words in the critical sentence. This, at first glance, appears to be in contrast with our finding that indirectness tends to be associated with decreased predictability. However, it is a well-known fact that requests, due to their potential to threaten the negative face of the speaker, are very frequently performed in indirect form following a politeness strategy (Brown & Levinson, 1987; Holtgraves, 1991, 1994). Indeed, in our present data, indirect replies that had implications for politeness, were only minimally less predictable than their direct counterparts (see Figure 4.2). Thus, it also possible that indirect replies used in Coulson and Lovett (2010) were in fact not that “unpredictable” due to their politeness function, which could explain why they did not see N400 differences between the direct and indirect condition.

A further consideration concerns the way indirectness has been operationalised in the literature. In more recent studies of indirectness, experiment were designed where the very same critical stimulus could be either direct or indirect depending on the preceding context (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; van Ackeren et al., 2016). While some studies attempted to equalise semantic similarity to context in direct and indirect stimuli by several means (e.g., Bašnáková et al., 2015; Bašnáková et al., 2014 and the present study), others used LSA – a measure of semantic relatedness – as a criterion to quantify and operationalise indirectness (Feng et al., 2017). In these studies, the cosine similarity based on latent semantic analysis (LSA) (Landauer et al., 1998; Landauer et al., 2007) between context and critical reply was used as a proxy for semantic similarity. In the current study, our direct/indirect stimuli were counterbalanced also for LSA-based cosine similarity and for further indicators of semantic relation (number or repeated lemmas, number of repeated pronouns, number of coreferences).

Nevertheless, subjects still perceived indirect stimuli as less semantically related to their context. This is likely due to the obvious imperfectness of using a sum of semantic vectors of individual words to obtain semantic information about a larger construction. All sequential and combinatorial information is lost in this case. LSA is indeed an imperfect tool that fails in the representation of various aspects of language such as lexical ambiguity, idiomatic meaning, metaphors, etc. Therefore, the present claims are limited to a set of stimuli that was matched based on the LSA-based cosine similarity between context question and critical utterance in the various conditions. However, other more contemporary distributional models such as BERT (Devlin et al., 2019) or ELMo (Peters et al., 2018) could offer a useful alternative to the currently used LSA. To sum up, our data show that an increased semantic distance from its context sentence might be an intrinsic property of indirect stimuli, as it closely correlates with perceived indirectness. On the basis of these results, it appears that using behavioural ratings of semantic similarity between context and critical utterance as a proxy for the degree of indirectness might be a sound approach (as in Feng et al., 2017).

Our study revealed the intrinsic relationship between the cognitive properties of indirectness, semantic relatedness, predictability, coherence and certainty of understanding. As such, our results are of relevance for any study making claims about specific features of indirectness, as the multiple implications for the related cognitive processes need to be taken into account. This applies, in particular, to studies aiming at drawing inferences on the brain loci of indirectness. In all of these cases, additional studies are necessary to disentangle which feature of indirectness, or which combination of features, are crucial for a specific brain locus to "light up". Current interpretations offered in the literature had so far been lacking on these aspects in many cases. In our study, we examined differences between direct and indirect speech acts that differed with regard to their speech act function and, in addition, speech act-matched sets where the critical speech act performed with the second sentence had the same speech act function. As mentioned, the factor "SA-matching" was involved in a 3-way interaction with In/Directness and Polarity, whereby the indirect items with negative polarity were also characterised by face threat, which, as we argue, led to relatively enhanced cognitive ratings for the indirect condition. We noted that, in the absence of a face-threat difference (i.e. the positive polarity items), the discrepancies between most cognitive ratings of SA-matched vs. non-SA-matched indirect speech acts were relatively more pronounced. In this context, we note again that, as to our knowledge, none of the previously published neurocognitive studies reported to have implemented such matching. It may therefore be that some of the brain activation signatures of indirectness reported so far may be due to a change in speech act function, rather than to indirectness *per* *se*. Therefore, we suggest to implement speech act matching in future studies of any neurocognitive differences related to in/directness, or consider the effects of a lack thereof.

4.4.4 Limitations and outlook

One criticism that can be raised concerning the present study, is to which degree the cognitive properties rated by lay subjects can be considered reliable. Patterns that we find in our data seem to confirm that the subjects had an appropriate understanding of these dimensions. First, the Directness ratings reflected the *a priori* categorisation of stimuli as direct or indirect. Second, the rating of Semantic Similarity between context question and critical replies was slightly higher (although not significantly) for direct positive replies than for direct negative replies in the SA-matched set. This seems reasonable, given that the latter, but not the former were a para-phrased form of the context question. Direct replies which entail a "yes", as opposed to those entailing a "no" consisted in a reformulation of the question's propositional content in an affirmative form, which might have increased the semantic similarity of the reply to the context question. For instance, if the context question is "Is your cat hurt?" and the confirmatory direct reply is "It got wounded.", the critical words "hurt" and "wounded" are closely related semantically and the propositional content of the two utterances is likewise similar. However, if the context question "Did he grow up in the country?" is followed by the disconfirming direct reply "He has always lived in the city.", there is less overlap of propositional content between the two utterances, although a semantic link between "country" and "city" can hardly be denied. Clearly subjects were sensitive to this difference although LSA was not. Third, the ratings provided by the subjects correlated significantly with the corresponding logRTs (see Appendix C.5). The explicit ratings provided by the subjects are therefore supported by the implicit measure of their reaction times even though subjects were only instructed to be accurate, but not to be fast, and in absence of any time constraint. To sum up, while lay subjects most likely have a more intuitive understanding of properties such as those rated here, it is very unlikely that they fully lack meta-linguistic understanding. Furthermore, it has to be pointed out that the goal of the present work was precisely to examine how/whether the linguistic definition of (in)directness is reflected in the perceived properties of indirectness, in order to inform psycho– and neurolinguistics studies of indirectness. Of course, the overarching goal of such studies is to investigate mechanisms of indirectness comprehension in the mind and brain of the average individual, who might indeed lack high degrees of meta-linguistic awareness.

Our interpretation of the 3-way interactions rests on Politeness Theory (Brown

& Levinson, 1987) combined with a specific effect of SA-matching. However, in the present study, we did not collect ratings of the perceived Politeness of the replies or of the perceived face-threat associated with the question-reply minimal dialogue. As the present results suggest that the perceived face-threat might play a role in how indirectness is perceived, future studies should consider evaluating such a dimension too, with the aim to provide more support to this claim. Additionally, in the present study we only assessed the dimensions that were related to our hypothesis, i.e. dimensions in which we expected direct and indirect replies to score differently. However, we did not include any negative control variable i.e. a dimensions unrelated to in/directness where we would not have expected direct and indirect replies to differ. One possibility, for instance, would have been to ask participants to provide grammatical acceptability ratings, which are not expected to vary depending on in/direct status of the utterance. Having such additional variable(s) was difficult in the present study, as this would have come with the risk of excessively fatiguing the subjects. Nevertheless, we acknowledge that including a negative control variable would have made our experimental design stronger.

Given the strong associations that we find here between the assessed dimensions, one could rise the question of whether subjects might just have systematically reported scores given along a given scale on the other scales for the same stimulus. Note however that the design of the rating procedure should have minimised such a potential issue, as each rating question was presented in a different rating block (see Section 4.2.3, "Experimental Procedure") such that the subjects never had to rate the same stimulus on all dimensions at the same time. This is also sup-ported by the individual subject trajectories reported in Appendix C.6, which indicate that it was not the case that same subjects provided same values across all ratings.

The present study investigated only a subset of types of indirectness (intended as Relevance implicature) that can be encountered in natural language. Indirect utterances might however not only be replies to questions and might not always implicate a "yes" or a "no". Also, they might convey many other types of speech acts other than *assertions*, *acceptance* and *rejection* (Holtgraves, 1991, 1998, 1999; Holtgraves & Robinson, 2020). Most notably, indirect *requests* which were the object of much previous research (Clark, 1979; Gibbs and Mueller, 1988; Holtgraves, 1994; Trott and Bergen, 2018; see Ruytenbeek et al., 2017 for a critical review), were not examined in the present study. However, we consider it possible that the present findings generalise to a degree to these other types of indirect speech acts. Also, specifically (indirect) *requests*, which are a face threat because they involve an imposition and therefore threat to the negative face of the hearer, could possibly follow a pattern similar to the indirect *declinations* of *offers* in our non-SA-matched set.

Finally, the way pragmatics in general and indirectness more specifically are used, might be the object of cross-linguistic and cross-cultural variation. The current work was based on stimulus material an English which was evaluated by a cohort of subjects who were native speakers of English. Also, the present study is in the prolongation of a long-lasting tradition of theoretical research in the field of pragmatics which is also mostly based on English language too. The degree to which the current findings extend to other languages and, more generally, other cultures should be the object of further investigation.

4.4.5 Conclusion

The present study investigated the cognitive properties of linguistic directness vs. indirectness of consecutive speech acts, here expressed by question and reply sentences, and how their cognitive properties are affected by other factors such as the speech act type of the reply, i.e. whether it is affirmative or disconfirming (factor "polarity"). Overall, indirect replies differed from direct ones insofar as they were perceived as less coherent with their linguistic context, more semantically distant from the linguistic context, less predictable and yielding more uncertain interpretations. These main differences were finely modulated by the type of speech act that they conveyed, such that indirect *declinations* of *offers* or *invitations* were evaluated more similarly to direct replies than the indirect *acceptances* were to their direct counterparts, possibly due to a face threatening function of the former. When such face issues were not present (positive replies) the cognitive ratings of indirect speech acts were relatively lower than their direct counterparts as compared to the situation with non-SA-matched stimuli, thus suggesting enhanced cognitive differences for non-matched in/direct speech acts. Furthermore, the properties that distinguished between direct and indirect replies were strongly inter-correlated. We conclude that linguistic indirectness is characterised by specific cognitive properties. We also argue that these features are not only occasionally associated with indirectness but that they are systematic and intrinsic to indirectness, as a cognitive manifestation of the linguistic concept of indirectness and thus represent genuine conceptual features of the phenomenon. These distinct properties most likely have differential impacts on the way indirectness is processed in the mind and brain. Therefore, this knowledge should be used on one hand to support, guide, but also challenge the interpretation of psycholinguistic and neurolinguistics studies on indirectness. Similarly, it provides a basis to improve future experimental designs that aim at understanding the individual contributions of brain areas or brain networks involved in understanding of indirectness. Finally, our findings also highlight how the specific type of speech acts performed indirectly along with the matching of direct and indirect items represent an important factor which can affect underlying mechanisms of comprehension of indirectness. Future studies should aim at understanding the mechanisms of indirectness comprehension while more systematically varying the type of speech act being performed indirectly.

Chapter 5

General Discussion

5.1 Summary of the findings

5.1.1 Study in Chapter 2

Previous studies of the neural correlates of speech act processing have focused exclusively on the comprehension modality and investigated the phenomenon in rather unnaturalistic laboratory settings (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019). The study reported in Chapter 2 addressed these limitations. The investigation of the neural correlates of the *request* vs. *naming* speech act was extended to the production modality and implemented in an interactive dialogue-like setting. This study allowed us to determine that dissociations between neural signatures of *naming* and *request* previously identified in the comprehension modality (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2019) were also identifiable in the production modality, during speech preparation. This dissociation was manifest in the form of a larger readiness potential for the *request* speech act, an ERP signal typically interpreted as an indicator of preparation of the motor system (Di Russo et al., 2017; Kornhuber & Deecke, 1965b; Shibasaki & Hallett, 2006). Source analysis suggested that the neural generators of these differences at the scalp level could be localized in the motor cortex. Therefore, we found evidence suggesting that, in qualitative terms, activations of the motor cortex are characteristic of the *request* speech act, when contrasted with the *naming* speech act. Given the similarity between the motor pattern of activation suggested by the results for the *request* speech act in production, and the motor patterns found for the same speech act in the comprehension modality, it is likely that motor activation is a "signature" of the *request* speech act. This motor activation characteristic of *requests* is likely related to the expectation that when a *request* is uttered, this linguistic action is typically followed by a motor (hand) action, that is, the handing in of the requested object. Therefore, these findings are in line with the TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014) that predicts that neural correlates of specific classes of speech acts are (among others) determined by the action sequence structures they are embedded in. In addition, in the broader picture of language processing, these findings are consistent with the position that similar neural systems are at work for language comprehension and language production.

5.1.2 Study in Chapter 3

Neuroimaging studies investigating comprehension of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2012; van Ackeren et al., 2016) can only identify brain regions that become more active in the co-occurrence of the presentation of indirect speech acts. However, they cannot demonstrate that these regions *causally* contribute to the processing of indirectness. In addition, these studies have typically contrasted indirect and direct speech acts carrying out different communicative functions, which could have acted as a confound. In Chapter 3 these limitations were addressed, by directing transcranial magnetic stimulation to the right temporo-parietal junction (rTPJ). This region was one of the regions previously identified in neuroimaging studies of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021) and is considered a region of the Theory of Mind brain network (Schulze & Buttelmann, 2021; Schulze & Tomasello, 2015; Van Overwalle & Baetens, 2009). In addition, comprehension of indirect speech acts and their respective direct controls was assessed both in the case of a speech act match and a mismatch. In the absence of TMS, indirect replies were processed more slowly than their direct counterparts, regardless of speech act matching. However, TMS stimulation of the rTPJ revealed different patterns depending on the SA-matching status. After TMS, the difference in reaction times between indirect and direct speech acts was still present when they were matched for SA-type; however, it was no longer detectable when they conveyed different speech acts. Also, stimulation of the rTPJ in the same participants affected their reaction times in a ToM task. Overall, this study showed no evidence of the involvement of the rTPJ (and possibly of ToM) function in the comprehension of indirect (vs. direct) speech acts, when the speech act type confound was controlled for. However, this study suggests that the rTPJ played a role in the processing of the speech act type rather than indirectness *per se*. Activations in the rTPJ that are reported in the literature were always based on contrasting indirect utterances with direct ones carrying out a different speech act. It is therefore possible that rTPJ is not causally involved in processing indirectness but rather in processing the

SA type carried out indirectly, which differed from the ones carried out directly. Another possibility is that processing of indirectness is associated with activations in the rTPJ but that these are not causally relevant, but instead reflect some form of post-processing.

5.1.3 Study in Chapter 4

Investigations of the neural basis of comprehension of indirect speech acts have previously identified a set of brain regions that are active during comprehension of indirectness (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011; van Ackeren et al., 2012; van Ackeren et al., 2016). The respective contributions of these active brain areas have been inferred based on reverse inference (Poldrack, 2006) and on the ascription of putative psycholinguistic properties to indirectness. However, the properties of indirectness had not been empirically investigated. In the study reported in Chapter 4 (some of) the ways in which indirect speech acts systematically differ from direct ones were investigated. Subjects were asked to rate in/direct speech acts by means of the indirect vs. direct contrast both with and without speech act change. The ratings revealed that overall, indirect speech acts were found to be less predictable, less semantically similar to their context questions, less coherent with their context questions, and understood with less certainty than their direct controls. Furthermore, differences between indirect and direct speech acts were amplified when speech act matching was lacking. This increased difference was possibly modulated by politeness dynamics (Brown & Levinson, 1987). Interestingly, overall, the aforementioned properties were strongly associated with indirectness, as demonstrated by strong correlations and principal component analysis, and it was not possible to disentangle them from it. We conclude that indirect speech acts are indeed intrinsically less semantically similar to and less coherent with their context questions, less predictable, and understood with less certainty than direct ones. Knowledge about these properties is relevant for investigating the cognitive and neural mechanisms that allow comprehension of indirectness. Furthermore, again, because SA-matching status affected the ratings, we conclude that this feature should be considered during future investigations of linguistic indirectness.

5.2 Significance

5.2.1 Processing of Speech Acts

One of the goals of the present work, specifically Chapter 2, was to determine whether the neural signatures of *request* vs. *naming* speech acts initially identified in the comprehension modality (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019; van Ackeren et al., 2012; van Ackeren et al., 2016) would extend to the production modality, demonstrating that specific speech acts correspond to modality-independent brain representations.

In the study presented in Chapter 2, contrasting the production of *request* actions with the production of *naming* actions revealed patterns of activations, including a larger readiness potential for *requests* (as opposed to *naming*). Both of these results can be interpreted functionally as increased activation in the motor system for *requests* given that (1) the readiness potential is considered an indicator of motor preparation originating from the brain motor's system (Di Russo et al., 2017; Kornhuber & Deecke, 1965b; Shibasaki & Hallett, 2006) and (2) source analysis suggested that the neural generators of the readiness potential in the present study were localized in the motor cortices, typically responsible for the representation of motor actions. Crucially, these activation patterns are highly convergent with a range of studies investigating the same speech act contrast in the comprehension modality using EEG (Egorova et al., 2013; Tomasello et al., 2022; Tomasello et al., 2019), MEG (Egorova et al., 2014) and fMRI (Egorova et al., 2016, see also van Ackeren et al., 2012; van Ackeren et al., 2016 for indirect *requests*). Indeed, across all these studies, neural activity associated with *requests* vs. *naming* could be traced back to the motor system (see Figure 2.4). Therefore, neural signatures of *request* speech acts seem to be robust across comprehension and production modality (see further discussion in Section 5.2.3) and across a range of methods of investigation, and consist (at least in part) of activations of the motor system. This study extended findings from the comprehension modality to the production modality and thereby provided support for models of language postulating that similar brain mechanisms are at work during comprehension and production (Pulvermüller, 2018; Strijkers and Costa, 2016, see Section 5.2.3 for further discussion of this latter point).

In addition, the study presented in Chapter 2 provides some indication that this motor activation associated with the production of *requests* might be found specifically in the hand motor cortex. This is highly convergent with the results of previous studies which found similar activation in the hand motor cortex, or in the vicinity thereof (Egorova et al. (2016), Tomasello et al. (2019), and van Ackeren et al. (2012), van Ackeren et al. (2016), see Figure 2.4). This is in line with the TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014), which predicts dissociations between the neural signatures of speech act types and, in addition, that these are grounded in the use of that very speech act in natural interactions, specifically in its typically associated intentions, assumptions, and action sequence tree (see Section 1.2.1). In the case of *requests*, a typical part of the action sequence tree is the reaction of the listener, who will then (usually) hand in the requested object or more generally produce an action in response to *requests*. The motor system activations in the case of *request* comprehension and production might therefore reflect the expectation of the response action being executed by the listener. This interpretation is consistent with previous findings that demonstrated how a readiness potential is detectable not only during the preparation of one's own motor actions but also during anticipation of the perception of others' motor actions (Bozzacchi et al., 2014; Kilner et al., 2007; Kilner et al., 2004). Interestingly, readiness potential-like responses have also been identified outside of the context of actions. In a series of studies, a progressive negative deflection localized at fronto-central scalp locations has been detected during the expectation of predictable stimuli of various natures, from man-made sounds (Grisoni et al., 2016; Grisoni, Mohr, et al., 2019), to phonemes (Grisoni & Pulvermüller, 2022), to words (Grisoni et al., 2017; Grisoni et al., 2021). Interestingly, source analysis locates the sources of these scalp activations in different sensorimotor regions, reflecting the semantic properties of the predicted stimulus (Pulvermüller & Grisoni, 2020) . For instance, expecting a footstep sound activates the motor cortex, where the neural representation of leg movements is located. Similarly, expecting an animal word e.g., "eagle" activates the areas of the visual system because visual properties are relevant to the concept of EAGLE. Therefore, overall, these findings have been interpreted as preactivation of the neural representation of the predicted stimuli (Grisoni & Pulvermüller, 2022). The presence of these negative slow-wave potentials in anticipation of one's own or other's actions, as well as in anticipation of predictable linguistic stimuli is in line with the interpretation given to the RP detected in the present study. That is, the activations in the motor cortex found for *requests* might be explained by the speaker's/listener's expectation that the requested object will be handed over (by means of a manual gesture) even if they do not perform any overt manual action themselves (e.g. because they are not the addressee of the *request*).

Therefore, altogether, the study presented in Chapter 2 in conjunction with previous research provides evidence that identical utterances used for different communicative purposes are associated with different neural correlates, demonstrating that speech act processing can be a valid object of neurolinguistic inquiry. In addition, the study demonstrates that a specific speech act type can be linked to constant patterns of neural activation, supporting the idea that different speech act types might have specific "signatures". Finally, it provides indications that the specific activation patterns for a given speech act type can be linked to and predicted by the intentions, assumptions, and action sequence trees associated with that very type of speech act, as postulated by Action Perception Theory (Pulvermüller, 2018; Pulvermüller et al., 2014).

5.2.2 Processing of Indirect Speech Acts

The studies presented in Chapters 3 and 4 addressed questions about the processing of indirect speech acts at the cognitive and neurobiological levels. This broader question was narrowed down to the characterization of (part of) the psycholinguistic properties of indirectness and to the testing of whether certain brain regions are indeed causally involved in the comprehension of indirectness. Overall, this work was conducted while controlling for the speech act type confound that was present in previous research and that was likely to have affected results. The implications of these results for investigations of indirectness from a neurocognitive perspective are threefold.

Role of ToM in comprehension of indirect speech acts

From a neurocognitive perspective, one central question regarding indirect speech acts is how the listener derives the implicated meaning from the utterance. As mentioned above, one of the processes that have often been hypothesized to contribute to the comprehension of indirectness is the process of ToM (also called ”mentalizing”), that is, the ability to understand other’s mental states such as intentions, goals, beliefs, desires, etc. (Baron-Cohen et al., 1985; Leslie, 1987; Premack & Woodruff, 1978). Because communication has been defined as a form of intention recognition (Grice, 1957) or as a means to manipulate (i.e. affect) the intentional or mental states of others (Tomasello, 2003), it does not seem surprising that intention-reading, or ToM, is implicit in any communication act. Indeed, neuroimaging evidence is compatible with these considerations and shows that the ToM network is active when people engage in communicative tasks (Kuhlen et al., 2017; Noordzij et al., 2010; Noordzij et al., 2009; Stolk et al., 2014; Willems et al., 2010). The question asked here, however, is whether the processing of indirect speech acts imposes even greater demands on the ToM network. Indeed, ToM might become more central to the processing of indirectness as a greater effort might be made to recognize the speaker’s intention which is conveyed more implicitly. In addition, a more in-depth assessment of the common ground between speakers might play an important role. Common Ground (CG) is the knowledge shared between conversational partners, that they are also aware of sharing (Clark, 1996; Stalnaker, 2002; Stalnaker, 1978). Specifically, understating indirect speech acts relies on using both contextual information, and general world knowledge, which are shared between the conversational partners. Therefore, ToM function might be needed to monitor this shared background information to be used to infer the intended meaning of indirect speech acts. Note that ToM might be involved in other aspects of social cognition beyond monitoring common ground.

Indeed, neuroimaging studies have consistently reported activations of the ToM brain network (Schulze & Buttelmann, 2021; Schulze & Tomasello, 2015; Van Overwalle & Baetens, 2009), specifically of the TPJs and of the mPFC, when subjects were asked to read and understand indirect (vs. direct) speech acts (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011). Although this finding was overall robust across studies, it suffered from two limitations. First, as discussed above, the speech act type expressed indirectly was typically different from the one expressed directly. Therefore, using such a contrast might capture not only the brain activations related to indirectness but also the neural signatures typical of these speech acts (see Section "The confound of speech act type" below). In addition, neuroimaging evidence is known to provide only correlational evidence for the engagement of a given area in the task of interest, but it cannot tell whether a given brain activation is merely epiphenomenal, e.g., reflects some post-processing that is not central to comprehension.

The work presented in Chapter 3 demonstrated that when contrasting indirect and direct speech acts that realized the same speech act type, that is, a contrast free of the SA type confound, no effect of rTPJ-directed TMS was detected. Importantly, stimulation of the same area did, however, affect performance in a ToM task. This demonstrated that the manipulation did indeed affect ToM processing, also minimizing the problem of reverse inference (Poldrack, 2006). Overall, therefore, no evidence for a causal role of the rTPJ - a key region supporting the ToM function in the brain - could be found in processing indirectness *per se*. Note, however, that this absence of the effect of stimulation should be interpreted with caution, because the absence of evidence is not evidence of absence. This lack of rTPJ contribution to the comprehension of indirectness *per se* might appear to be in contrast with the previous neuroimaging literature, which instead found this region to be active and classically interpreted it as evidence for the involvement of ToM. The key to solving this apparent incongruity might lie in the types of speech acts carried out indirectly. Indeed, these other fMRI studies did not use the comparatively unconfounded contrast that we used here and instead used direct and indirect speech acts that differed in their speech act type. Interestingly, in the study presented in Chapter 3, some indication that the TMS manipulation affected behavioral measures was indeed found for the non-SA-matched contrast. This pattern of results seems overall congruent with the fact that the rTPJ might play a causal role in processing information related to speech act type rather than indirectness itself (see dedicated section below, “The confound of speech act type”). Therefore, rTPJ activations identified in previous neuroimaging studies might be related to this confound, rather than to indirectness itself.

Various scholars have asked what the role of ToM is in processing various pragmatic phenomena (metaphors, irony, various implicatures, etc.). Over the years, two positions have emerged. The first position sees ToM processing as being central to pragmatic processing to the same degree regardless of the exact nature of the pragmatic phenomenon at stake. For example, according to Relevance Theory, all forms of pragmatic phenomena are understood by appealing to the principle of Relevance and are processed in a "pragmatic module" which in turn is part of a 'ToM module" (Sperber & Wilson, 1996, 2002). In contrast, others have opposed such a "monolithic" view of pragmatic processing and have proposed that ToM is engaged differently in the comprehension of different pragmatic phenomena. According to this latter view, phenomena that are less context-variant, such as scalar implicatures, rely more on linguistic knowledge than on ToM, whereas others, such as irony, rely more on ToM (Andrés-Roqueta & Katsos, 2017; Jary, 2013; Kissine, 2016). In such a framework, the position of indirect speech acts along the ToM gradient is not clearly defined. However, the findings illustrated in Chapter 3, that is, the absence of the effect of rTPJ-directed TMS during comprehension of indirectness when compared to SA-matched direct controls, is consistent with a lesser need of ToM for processing of Indirect Speech Acts.

In sum, neuroimaging studies have suggested an involvement of the rTPJ in the comprehension of indirectness. However, in the study presented in Chapter 4, no evidence was found in this regard when the indirect speech acts were contrasted to the direct ones carrying out the same type of speech act. These results are consistent with the fact that no additional ToM involvement is required for comprehension of indirect speech acts. Instead of ToM, other processes - such as those discussed in the Section below ("Distinctions between direct and indirect speech acts") - could play an important role.

Distinctions between direct and indirect speech acts

Investigations of indirect speech act comprehension agree that it is a costly process because response times to indirect speech acts are typically longer than those to matched direct ones (Feng et al., 2017; Feng et al., 2021; Hamblin & Gibbs, 2003; Holtgraves, 1999; Jang et al., 2013; Shibata et al., 2011). This additional effort suggests that additional cognitive processes might be engaged in the comprehension of indirect speech acts compared to direct ones. When attempting to more precisely characterize these processes, the main sources of information have been the insights from earlier theoretical research and more recent neuroimaging evidence. For instance, earlier work by Searle and Grice suggested a multi-step inferencing process that emphasized the role of rationality, the integration of general world knowledge, and the reading of the intentions of the speaker (Grice, 1975; Searle, 1979). In the meantime, neurolinguistic research highlighted a range of brain areas that are active during the processing of indirectness, most notably the bilateral MTG and bilateral IFG, which were typically considered to contribute to semantic integration and coherence building, and the mPFC as well as the TPJs for ToM processing (Bašnáková et al., 2015; Bašnáková et al., 2014; Bendtz et al., 2022; Feng et al., 2017; Feng et al., 2021; Jang et al., 2013; Shibata et al., 2011). The logic followed here was typically the reverse inferencing, that is, inferring that given cognitive processes (e.g., ToM or coherence building) are at work solely because brain regions that were previously found to support such processes are found to be active. However, given that the same brain areas can carry out multiple functions in different task contexts, inferring that a cognitive process is at work solely on the basis of neuroimaging evidence is not fully granted and has been the object of criticism (Poldrack, 2006). Although it is often difficult not to resort to the use of reverse inference, its limited conclusions can greatly benefit from converging evidence originating from other empirical approaches.

The findings presented in Chapter 4 play an important role because they complement reverse inferencing-based findings from neuroimaging studies, and have the potential to support their conclusions. In addition, they suggested the involvement of cognitive processes that were not hypothesized in the past. In particular, in Chapter 4 it was found that indirectness comes together with a "package" of properties, which would justify the engagement of corresponding cognitive processes during comprehension of indirect speech acts and therefore also of the corresponding neural systems. For instance, compared to their direct counterparts, indirect speech acts were found to be less semantically related to and less coherent with their preceding linguistic context. This is consistent with the neuroimaging findings that interpreted the bilateral MTG and bilateral IFG to support the cognitive processes of semantic processing and coherence building (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021) and substantiated this claim. In addition, consistent with previous behavioral ratings (Lee & Pinker, 2010), indirect speech acts were found to be interpreted with less certainty. This property has so far not been much considered in behavioral and neuroscientific investigations of indirectness. It suggests that some of the brain areas active during the processing of indirectness, such as the dorsal part of the mPFC, might in fact be processing the related uncertainty or weighting out alternative interpretations. Finally, indirect speech acts were found to be less predictable, suggesting another so far unconsidered possibility, that is, that prediction and prediction resolution processes might be at work during comprehension of indirectness. For instance, neural signatures of prediction error might be detectable, e.g., in the form of larger N400 effects building up along the sentence (Grisoni et al., 2017; Grisoni et al., 2021; Kutas & Federmeier, 2011).

In sum, the work presented in Chapter 4 substantiated some of the findings from neuroimaging evidence. It provided converging evidence that semantic and coherence processes and related neural systems might be engaged during the comprehension of indirectness. In addition, it suggested that uncertainty processes and prediction resolution processes should also be engaged, which is also consistent with, but a novel interpretation of previous neuroimaging findings. These processes highlighted here are most likely not exhaustive. They might add up to other processes such as ToM to process the speaker's intentions (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017; Feng et al., 2021; Grice, 1975; Searle, 1979) or the recently suggested working memory (Zhang et al., 2021) which might be needed to maintain contextual information active, which is relevant for the comprehension of indirect but not direct speech acts. Altogether, these findings support the view that indirectness is a complex and multi-faceted phenomenon and that several cognitive processes might be jointly at work in processing it.

The confound of speech act type

In the General Introduction (Section 1.3.3), it was pointed out that previous investigations of comprehension of indirect speech acts from both a behavioral and a neuroimaging approach have typically contrasted indirect speech acts with direct ones that did not convey the same type of speech act. There was therefore a lack of speech act matching (SA-matching). For instance, much research has been conducted on indirect *requests* (a directive speech act) compared to direct non-directives (Coulson & Lovett, 2010; van Ackeren et al., 2012). It was argued that such contrasts used to investigate indirectness might be confounded by this difference in speech act type. Therefore, differences in behavioral measures (e.g., RTs) or in neural measures (e.g., EEG, BOLD signal) between direct and indirect speech acts in previous studies might not only capture the correlates of indirectness processing, but also those of speech act processing. Indeed, certain speech acts appear to have relatively stable correlates, as discussed in the previous section (Section 5.2.1) and as supported by previous studies (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019). In addition, further research has shown that neural patterns typical of the processing of a certain speech act can also be detected when this speech act is performed indirectly (van Ackeren et al., 2012; van Ackeren et al., 2016).

The results presented in Chapters 3 and 4 indeed demonstrated the confounding effect of the lack of SA-matching. In these studies, we purposefully tested two different sets of stimuli. The first set included direct and indirect replies that were matched for speech act type (both were *assertives*) providing a contrast that was therefore free of the confound related to speech act type. In a second set, however, direct and indirect replies did differed in the type of speech act that they carried out (direct replies were *assertives* and indirect ones were either *acceptance* or *rejections* of offers/invitations), and were therefore more similar to the stimulus material used in previous studies by other groups. By using both a confounded and unconfounded set, we could identify whether the presence or absence of speech act matching affected our measures of interest. In both studies, this was the case. In the study presented in Chapter 3, when the rTPJ was stimulated, a different pattern of results appeared for indirect replies in the SA-matched or non-SA-matched contrast. That is, if in the matched set indirect replies were responded to more slowly than direct ones, this was not the case for the unmatched ones, where the difference was absent. Concerning these results, it is also interesting to note that differences between matched and non-matched indirect speech acts and their direct counterparts emerged only after TMS stimulation of the rTPJ and were not detectable without it. This suggests that the rTPJ might have been causally involved not in the processing of indirectness, but rather in the processing of the specific speech act type being carried out indirectly. Considering that the non-SA-matched set consisted of *rejecting* and *accepting* offers, it is possible that the rTPJ was particularly engaged in supporting the ToM function possibly required to process more relevant social implications of *rejecting* and *accepting* offers (e.g., the effect on the speaker's mental state) linked to these specific speech act types. Similarly, the behavioral ratings presented in Chapter 4 showed that indirect speech acts differ from direct ones on a range of cognitive properties (see next section for more details). Interestingly, when the direct and indirect replies being contrasted did not carry out the same speech act, these differences appeared to be even more marked.

Overall, for the first time, it was demonstrated that SA-matching acts as a confounding factor in the investigation of indirectness. An interesting question is how the presence of such an SA-confound might have affected previous research. In Chapter 4, I reported that in the non-SA-matched contrast, the difference between direct and indirect replies was larger than in the SA-matched set (specifically the "yes" items) across all properties. It is therefore possible that previous neuroimaging research might have partially overestimated the difference in neural correlates between direct and indirect speech acts. Furthermore, the speech acts realized indirectly in previous research, where reported, were often *requests*, *excuses*, and *negative opinions* (Bašnáková et al., 2015; Bašnáková et al., 2014; Feng et al., 2017). Besides their marked emotional connotation, these speech acts are all likely to require a deeper assessment of the common ground and a better anticipation of the listener's reaction to the utterance. These speech acts might therefore be particularly reliant on ToM skills, but also on affective processing (see Bašnáková et al., 2014, for instance). Activations in the neural circuits underlying ToM processing or in those underlying affective processing might therefore have been caused by speech act processing rather than by indirectness, which is in line with the finding of Chapter 2 that no causal effect of the rTPJ could be found for indirect speech acts when these were contrasted with direct matched controls.

Future investigations of indirectness will, because of methodological reasons, still require comparing indirect speech acts to direct control speech acts. For this reason, it becomes essential that these are matched in terms of speech act type if one aims at isolating the neuronal and behavioral correlates of indirectness. Conversely, the use of direct and indirect utterances that are not matched for speech act type comes with the risk (or possibility) of capturing unrelated speech act type processing. Therefore, future research should be conducted in awareness of the speech act confound. This should inform the choice of speech acts to be compared and motivate more transparency in how they are reported. Ideally, the SA confound should be entirely avoided by comparing direct and indirect speech acts of the same type. In the present work, for instance, direct and indirect assertives were compared, but any other speech act could be chosen in principle. In addition, especially if no SA-matching is applied, the types of speech acts realized in the direct and indirect conditions should be systematically reported in order to provide additional information helpful for the interpretation of the results.

To sum up, Chapters 3 and 4 provided evidence that a lack of SA-matching when contrasting indirect vs. direct utterances acts as a confounding factor and can affect the outcomes in both behavioral and neuroscientific studies. Previous research did not control for speech act type and might have provided confounded results. A better experimental approach in the future might be to compare only direct and indirect speech acts that realize the same type of speech act.

5.2.3 Neurobiological models of language

Investigating pragmatic processing at the neural level provides results that can also contribute to evaluating current neurobiological models of language. In particular, three of the many outstanding questions in this area can be addressed here.

A place for pragmatics

In the work presented here, particularly in Chapters 2 and 3, it becomes evident that when pragmatic processing occurs, the brain acts differently. Both studies contrasted identical utterances presented with different communicative functions or in different pragmatic contexts and demonstrated how, despite the fact that subjects were perceiving identical linguistic forms, the corresponding neural correlates were different. These data are consistent with several other studies demonstrating how various pragmatic factors, ranging from embedding in a social-communicative setting (Goregliad Fjaellingsdal et al., 2020; Kuhlen et al., 2015) to monitoring of common ground (Jouravlev et al., 2019; Rueschemeyer et al., 2015), to presupposition (Domaneschi et al., 2018; Masia et al., 2017), and many others (Hagoort & Indefrey, 2014; Noveck & Reboul, 2008; Sauerland & Schumacher, 2016) are associated with different neural activation patterns.

In Section 1.3.4 of the Introduction, it was highlighted that most current models of the neurobiology of language fail to account for pragmatic processing by either not considering it (Hickok, 2012; Hickok et al., 2011; Hickok & Poeppel, 2007) or by doing so only very superficially (Friederici, 2011; Indefrey, 2011; Indefrey & Levelt, 2004). It is clear that such models cannot explain the aforementioned effects related to pragmatics. Instead, the findings presented here are a strong argument for pragmatic processing being associated with specific brain signatures and for the inclusion of pragmatic processing in general models of the neurobiology of language. Any of such models, above and beyond explaining structural aspects of language, must also explain the dissociations and the activation patterns related to pragmatic processing, and ideally provide a mechanistic explanation thereof.

Of the two models of language that explicitly also consider pragmatic processing - the TAPCo and the MUC models - the presently found results on speech acts and indirect speech acts processing are best explained by the TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014). The TAPCo model postulates that the neural representations of different speech acts depend on. or are "grounded" in, the action sequence trees in which these speech acts are embedded and in the intentions and assumptions to which they are linked. Therefore, speech acts that are accompanied or followed by physical actions, such as *requests*, are at least partially represented in the brain's motor system, as reported in Chapter 2 as well as in previous work (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019; van Ackeren et al., 2012; van Ackeren et al., 2016). Furthermore, in Chapter 3 the results found in the TMS experiment suggested a causal involvement of the ToM region rTPJ only for certain speech acts when expressed indirectly, but not for all speech acts. These speech acts that appear to rely on the rTPJ (*accepting* and *rejecting offers/invitations*) were indeed those that seemed to be associated with a larger quantity of assumptions and intentions. In contrast, the MUC model (Hagoort, 2013, 2014, 2019) postulates that certain pragmatic phenomena might be associated with greater involvement of ToM function and therefore of the brain's ToM system, however, it fails to predict and provide a mechanism for the involvement of modality-preferential brain areas in the processing of certain speech acts, such as the involvement of the motor cortices for *requests*.

Therefore, overall, the present results rejoin multiple previous studies in demonstrating that pragmatic processing can be related to specific neural activation patterns. It is therefore imperative for a valid neurobiological model of language to also provide possible mechanisms underlying pragmatic processing (see, e.g., the TAPCo model).

Language as a grounded system

Another debated issue is whether language function relies solely on amodal (or multimodal) brain systems, or whether it also draws on modality-preferential brain areas, such as motor or sensory areas. The study presented in Chapter 2 is of particular relevance in this debate because it provides evidence that the brain's motor system is active when *requests* are processed, converging with several previous studies (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019; van Ackeren et al., 2012; van Ackeren et al., 2016). Therefore, at this point, an amount of evidence has accumulated for the role of the motor system, a modality-preferential brain area, in the processing of pragmatic aspects of language.

This finding parallels findings regarding the processing of other types of linguistic information. Several studies investigating phonological processing have demonstrated how the motor cortex is not only *active* (Pulvermüller et al., 2006; Strijkers et al., 2017) but even *causally relevant* (D'Ausilio et al., 2009; Fadiga et al., 2002; Schomers et al., 2015) for the processing of phonological information, so that parts of the motor cortex that are involved in producing the articulatory movements for specific phonemes are also engaged for the perception of the corresponding phonemes (see Schomers and Pulvermüller, 2016 for a review). Similarly, when focusing on semantic information, different patterns of activations in modality-preferential brain areas have been reported depending on the perceptual attributes of the referents. If words stand for referents that have particularly relevant visual features such as shape or color (e.g., "dark", "rectangle"), they were found to be processed partially in the visual cortex (Pulvermüller & Hauk, 2006). Similarly, words with auditory meanings (e.g., "violin", "telephone") were partially processed in the auditory cortex (Kiefer et al., 2008), and taste-related meanings (e.g., "cinnamon", "cake") in regions standing for gustatory perception (Barrós-Loscertales et al., 2012). Furthermore, the words that refer to different types of actions (e.g. 'kick', 'lick') somatotopically activate the corresponding part of the motor cortex (Grisoni et al., 2016; Grisoni et al., 2017; Grisoni, Moseley, et al., 2019; Hauk et al., 2004). Some evidence exists for these activations in distributed modality preferential brain areas to also be causally relevant (Pulvermüller et al., 2005; Vukovic et al., 2017; Willems et al., 2011).

Altogether, these results are inconsistent with models postulating that the various levels of representation of linguistic stimuli are abstract and therefore independent from the neural circuits responsible for action and perception. In these views, language is represented in a specific set of amodal brain regions, and only "executive" (preparation and execution of articulation) and "perceptual" processes (e.g., perceiving phonemes), are located in modal brain areas such as the articulatory motor and auditory cortex respectively (Friederici, 2012; Hickok, 2012; Hickok & Poeppel, 2007; Indefrey, 2011; Indefrey & Levelt, 2004). Instead, it appears that language function is "grounded" at various levels of representation (phonological, semantic, pragmatic) and is also represented in modality-preferential brain areas. These findings are therefore consistent with distributed neurobiological models of language (Pulvermüller, 2018; Pulvermüller et al., 2014; Strijkers & Costa, 2016).

Same neural circuits for language comprehension and production

Another debated issue in the field of the neurobiology of language is whether comprehension and production processes rely on the similar brain systems. The work presented in Chapter 2 speaks to this issue. While in the study no direct comparison between comprehension and production of naming and request actions was performed, the neural signatures of *requests* (vs. *naming*) in the production modality were markedly similar to those found in previous studies in the comprehension modality (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019, see also van Ackeren et al., 2012; van Ackeren et al., 2016). These findings are difficult to explain by neurobiological models of language that do not offer an integrative account of speech production and comprehension (Friederici, 2011; Indefrey, 2011; Indefrey & Levelt, 2004).

In contrast, other models of language (Pickering & Garrod, 2004, 2013; Pulvermüller, 2018) explicitly predict that comprehension and production rely on the same representations and that they do so along all facets of the linguistic stimulus, ranging from phonological to lexical to semantic to syntactical. Indeed, such models are largely supported by an amount of behavioral evidence indicating that perceiving linguistic utterances with specific characteristics can facilitate the production of utterances with the same characteristics (Pickering & Garrod, 2004) and by neural evidence showing that activating the same phonological, semantic, or syntactic representations relies on the same brain regions (Fairs et al., 2021; Menenti et al., 2011; Segaert et al., 2012; Strijkers et al., 2017, for a review see Menenti et al., 2012). Examining pragmatic processing in this light extended these previous works and once again demonstrated that similar linguistic representations come into play in language production and comprehension.

5.2.4 Naturalistic approaches to neurobiological investigations of language

A further contribution of the present work, particularly the study presented in Chapter 2, is the implementation of a naturalistic study paradigm. Classically, psycho- and neurolinguistic studies have relied on the use of highly controlled paradigms, with stimuli presented in written form on a computer screen or via headphones while the participants sit alone in the experimental chamber. Using such study designs presents the clear advantage that the pre-selected stimuli can be presented with high temporospatial precision while maintaining substantial control over any other contextual factor that can then be held constant. This classic experimental setting has therefore been extremely useful for the ground-laying work in psycho- and neurolinguistics conducted in recent decades.

However, such a “classical” laboratory setting is undeniably very far removed from real-life language use. First, in naturalistic communication, language is not decontextualized, but occurs in a specific physical setting and in a specific situational context. These factors are considered by comprehenders in communication and can shape the ongoing linguistic processes (see, e.g., Knoeferle and Crocker, 2006, 2007; Knoeferle and Guerra, 2016). Second, the “classic approach” treats linguistic behavior as a monologue, whereas linguistic behavior in naturalistic situations most typically takes the form of dialogue (Pickering & Garrod, 2004) and therefore involves at least two conversational partners. These typically do not just *listen* or *speak*. Instead, an interactional dimension is present, so that role-switching occurs dynamically. Third, an intentional dimension is present, so that when exchanging with someone in dialogue, the goal is to recognize the other’s communicative intention and make one’s own recognizable (Grice, 1957). Furthermore, this intentionality is shared and rests on cooperative behavior (Grice, 1975), so that communication can be considered a form of joint activity (Clark, 1996). Because language function has classically been investigated in the absence of these factors, one might argue that it is unclear how current cognitive and/or neurobiological models of language function are representative of linguistic processes in natural communication. The problem becomes even more severe when the object of interest is pragmatics itself.

Interestingly, recent investigations have suggested that language in more naturalistic communicative settings might indeed affect the processing underlying language function (see Kuhlen et al., 2015 for a review). Several studies found that neural signatures of perception of communicative non-verbal signals were different from those of perception of the same signals in a non-communicative task (Noordzij et al., 2010; Noordzij et al., 2009; Stolk et al., 2014). Similarly, producing speech in a communicative vs. non-communicative situation was associated with different patterns of brain activations, particularly in brain areas underlying ToM function (Kuhlen et al., 2017; Willems et al., 2010). In addition, partner presence during a task might affect linguistic processes by allowing alignment between speakers (see e.g. Kuhlen and Abdel Rahman, 2017; Pickering and Garrod, 2004) or by involving additional processes to monitor shared knowledge between speakers (Jouravlev et al., 2019; Rueschemeyer et al., 2015). In light of these studies, it becomes important to examine which and to what degree neurocognitive processes identified in "classic" experimental set-ups extend also to naturalistic ones, while maintaining as much experimental control as possible (see, e.g., Kuhlen and Brennan, 2013).

The study presented in Chapter 2 represents a successful attempt to move to a more naturalistic investigation of linguistic-pragmatic phenomena. In the study, a confederate interacted with the experimental participant by responding non-verbally to their *naming* and *requesting* speech acts, in the presence of physical objects. By these means, all situational, intentional, and interactional aspects of communication were integrated into the experimental design while maintaining several aspects of the experiment under control (e.g., the words to be uttered to produce the speech acts). The outcome of the study has a theoretical relevance, as it was found that the signatures of *request* identified in previous studies in "classic" passive listening or reading conditions (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019) also extended to the more naturalistic experimental paradigm. In addition, the outcome has a methodological relevance as it rejoins the few previous studies demonstrating that it is possible to achieve more naturalistic paradigms in the laboratory and record brain activity simultaneously (see e.g., Goregliad Fjaellingsdal et al., 2020; Kuhlen and Abdel Rahman, 2017; Kuhlen and Rahman, 2021; Mandel et al., 2016).

In sum, the study presented in Chapter 2 is a contribution to moving the field toward a more naturalistic investigation of the neural processes underlying language function, and it demonstrated that the neural signatures of *requests* found in previous "classic" experimental paradigms also extend to more naturalistic set-ups.

5.3 Limitations and future perspectives

Although the research presented in this thesis provided valuable insight into the neurocognitive basis of language, in particular the two linguistic-pragmatic phenomena of speech acts and indirect speech acts, it also has certain limitations, which can be the starting point for future research.

Speech Acts

Concerning the investigation of the neural basis of speech act processing, the work presented here follows a previous line of work that has focused on the specific comparison between speech acts conveyed by single-word utterances. This approach allowed us to assess and qualify differences in the neural representations of such linguistic actions while minimizing confounds. However, although communication by single words is possible and indeed practiced (e.g. holophrases during child development; see Dore, 1975; Tomasello, 2003), human communication typically unfolds in the form of sentences. For this reason, future research should assess whether the present findings extend to when the speech act is realized by a sentence rather than by a single word. Some first steps in this direction have been taken by Tomasello et al., 2022.

The present investigation of the processing of *naming* and *request* speech acts in the production modality, in conjunction with previous studies in the comprehension modality, addressed the question of similar vs. different systems for production and comprehension (see Section 5.2.3). However, in this study, no direct comparison between the neural processes in comprehension and production was possible. The conclusion was based on a qualitative comparison between the outcomes of previous studies in the comprehension modality and those of the present one in the production modality. A direct comparison between the two would provide the ultimate evidence for similar pragmatic processes during comprehension and production. To follow up on the present work, future experiments might assess and compare both modalities in the same experimental subjects and with the same stimulus material - an approach that has already been used to test other domains of linguistic processing (e.g., Fairs et al., 2021; Menenti et al., 2011; Segaert et al., 2012).

A further relevant question in the neurobiology of language that has not been addressed in the present dissertation is the temporal unfolding of different aspects of language processing. So far, in the comprehension modality, converging evidence has been found that speech act related information is processed early on (about 200 ms post critical stimulus onset) (Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019) and in parallel with semantics (Egorova et al., 2013). These studies provided support for so-called *parallel* models of language processing (Pulvermüller, 2018; Strijkers & Costa, 2016; Strijkers et al., 2017) which postulate that different aspects of a linguistic stimulus (e.g. phonological, semantic, pragmatic, etc) are processed at the same time. In contrast, these data are inconsistent with so-called *serial* models proposing that different aspects of the linguistic stimulus are processed sequentially, in a specific order, from phonological, to syntactic to semantic to pragmatic in comprehension and in the opposite order for production (Friederici, 2011; Indefrey, 2011; Pickering & Garrod, 2004). It is precisely in production that the temporal relation between the processing of speech act type in relation to other types of linguistic information has not been tested yet. The study presented in Chapter 2 could not contribute to this question because only the pragmatic factor was part of the experimental design. Future studies might manipulate pragmatic properties such as speech act type orthogonally to semantic or phonological properties to determine whether these types of information are processed in parallel or serially (see, e.g., the approach taken by Fairs et al., 2021; Miozzo et al., 2015; Strijkers et al., 2017) in the production modality.

Research so far (Egorova et al., 2014; Egorova et al., 2013, 2016; Tomasello et al., 2022; Tomasello et al., 2019), including the work presented in Chapter 2, has demonstrated by using different methods to measure brain activity that activations in the brain's motor system are a "signature" of the request speech act. However, given that the methods used (i.e., EEG, fMRI and MEG) provide only correlational evidence, it is still possible that these activations reflect some post-processing or epiphenomenal processing but that they are not *causally* relevant for the comprehension and production of requests. Future work should therefore assess whether these representations in the motor cortices are also functionally relevant. This could be done by testing patient populations with lesions in the motor cortex or by inducing transient "virtual lesions" by using TMS, similar to the approach taken in Chapter 3.

The results presented in chapter 2 were consistent with the TAPCo model (Pulvermüller, 2018; Pulvermüller et al., 2014), which postulates that the neural representations of speech acts are "grounded" in the action sequence trees, intentions, and assumptions they are associated with. The work conducted so far on speech act processing has focused mainly on the contrast between *naming* and *request* speech acts, which are respectively part of the *assertive* and *directive* speech act classes in Searle's taxonomy (Searle, 1979). However, substantial support for the generalizability of the TAPCo model would be provided by testing its predictions not only in the case of *naming* and *request* actions but also in a wider range of speech acts, possibly belonging to different Searlean classes (Searle, 1979).

Indirect Speech Acts

The findings presented in Chapters 3 and 4 on indirect speech acts argue that previous investigations of this linguistic-pragmatic phenomenon have examined a confounded case of indirectness and that indirect speech acts have multiple properties: they are less predictable, less coherent with and semantically similar to the context, and interpretable with less certainty. These properties of the stimulus are very likely to afford corresponding brain processes; however, except for the study presented in

Chapter 4, this has never been tested with unconfounded stimulus material. One first step to addressing this gap could be to conduct a neuroimaging experiment using the unconfounded stimulus set used in Chapters 3 and 4. A particularly interesting question would be whether activations in the ToM system, for instance in the rTPJ and in the mPFC, would not be detected any longer in the absence of the confound of speech act type, as suggested by the study presented in Chapter 3. A further step would be to understand how these neural correlates of indirectness without speech act type confound are relatable to the properties identified in Chapter 4, that is, which brain systems are responsible for processing which aspect of the indirect speech act. Because these various properties are strongly correlated, a parametric approach to neuroimaging data might not be successful. Instead, a promising approach would be to compare the BOLD response of indirect replies (vs. direct controls) to those of direct replies instantiating one of the properties of interest. For instance, one could compare patterns of activations to indirect replies (vs. direct controls) to those of comparably unpredictable direct replies (vs. predictable direct controls). The conjunctions between these two activation patterns should be indicative of the brain regions processing that process the unpredictability of indirect speech acts. This approach, here applied to predictability, could then be extended to other properties.

Next, the temporal aspect of the neural processing of indirect speech acts has often been neglected (see, however, Coulson and Lovett, 2010). This is likely to be because of the methodological challenges associated with such an approach. In short, such methods typically require focusing on a specific time range of the signal that coincides with the moment in which a specific cognitive process of interest comes into play. However, indirect speech acts are best realized by sentences (rather than single words), and no specific time point is identifiable in which "indirectness" comes into play. Therefore, there is no "critical time window" to examine. Nevertheless, the investigation of indirect speech acts using methods with high temporal resolution might still be possible, if appropriate hypotheses are made. For example, Chapter 4 describes how indirect speech acts are less predictable than their direct counterparts. This unpredictability assessed at the behavioral level in the form of ratings might become evident at the neural level in the form of neural markers of prediction error, such as the N400 EEG component (Grisoni et al., 2021; Kutas & Federmeier, 2011). Specifically, an N400 response building up at each word in the sentence could be larger for indirect than direct utterances.

Finally, the present work has focused on a narrow range of indirect speech acts, namely *non-conventionalized* indirect *responses* to *polar* questions. However, indirect speech acts might also be used in response to open questions, or might also be simply used as a "stand-alone" utterance, without being embedded in a conversational sequence. Future work will need to clarify whether our present findings also extend to these uses of indirectness. It is possible that these latter uses of indirectness require even more processing than the ones examined here, because of the decreased constraint exerted by the preceding question or because to the lack thereof. In addition, indirect speech acts that are "conventionalized" or "standardized", that is, indirect speech acts whose illocutionary force is conventionally bound to the linguistic form used, might be processed differently (Clark, 1979; Gibbs, 1986; Morgan, 1978; Stefanowitsch, 2003). For instance, the constructions "Can you VP" or "Would you VP" (as in "Can you pass the salt?") are typically used to make indirect *requests*. However, because of the form-function pairing, a "short-circuited" inference might be sufficient, or no inference at all might be needed to understand the utterance (Morgan, 1978; Stefanowitsch, 2003). Although it has been shown in a behavioral priming experiment that subjects are less likely to process the literal meaning of a conventionalized indirect request than the non-literal one (Gibbs, 1979), no study has so far examined the neural correlates of conventionalized vs. non-conventionalized indirect speech acts.

Toward a framework for direct and indirect speech acts

One of the conclusions from the study presented in Chapter 2, was that the *request* speech act shows stable neural correlates across modalities (see Section 5.2.1). The conclusions from Chapters 3 and 4 indicate that both behavioral and neural responses to indirect speech acts are affected by the type of speech act being carried out (see Section 5.2.2). It appears, therefore, that the pragmatic phenomena of speech acts and indirect speech acts interact with one another. What is not fully clear, however, is *how* exactly these interactions can be explained. Although it is premature to propose an overarching model of how direct and indirect speech acts are processed in the brain, the results presented so far suggest that the neural representation of a given speech act (e.g., of a *request*, *offer refusal*, etc.) might be active also when the speech act is carried out indirectly. This possibility is also supported by studies that found that indirect *requests* are associated with activations in the motor system, similar to direct *requests* (van Ackeren et al., 2012; van Ackeren et al., 2016). This could explain why, for instance, *accepting* or *rejecting an offer*, which might require more ToM processing than just making an *assertion*, appears to be causally supported by the rTPJ as suggested by in Chapter 3. Such an account would predict that the patterns of activations related to the processing of a given indirect speech act reflect both the signatures of the intended speech act (i.e., the illocutionary force) and those of indirectness. In other words, a given speech act type could have specific brain signatures independently of how it is carried out (direct vs. indirect) and be associated with the neural correlates of indirectness in the case of it being carried out indirectly. Therefore, the signatures of the speech act type might vary from speech act type to speech act type. For instance, the signatures of *requests* might rely on the brain's motor system, while those of other speech act types might have their own specific patterns of activations, possibly rooted in their use in communication (Pulvermüller, 2018; Pulvermüller et al., 2014). However, signatures of indirectness might involve those brain systems involved in the processing of predictability, coherence, semantics, and certainty (and possibly more properties). Future studies might need to test these hypotheses. One first experimental approach would be to further explore how different types of (direct) speech acts are realized in the brain. In a second moment, it would become possible to systematically vary speech act type and indirectness independently from one another. These latter experiments could then help to better disentangle effects related to indirectness and speech act type and to better understand how the two might interact.

5.4 Conclusion

The present dissertation examined the neuro-cognitive processes involved in processing communicative intention conveyed through language using a range of psycho- and neurolinguistic methods. The focus was on two pragmatic phenomena: speech acts and indirect speech acts. The first study found that producing the same words with different speech act functions (such as *naming* and *request*) was associated with different electrophysiological signatures. In particular, *requests* were associated with greater activity of the brain motor system, which can be explained by an anticipation of the listener's handing-in action. These dissociations were similar to those found by previous studies in the comprehension modality, providing some evidence that representations of communicative function might be shared between comprehension and production modality. The second study found that comprehending indirect speech acts was more costly than comprehending direct ones, but that the right temporoparietal junction did not play a causal role in the comprehension of indirect speech acts when compared to well-matched controls. The third study found several differences between direct and indirect speech acts, including lower predictability, coherence with context, semantic relatedness to context, and understanding certainty, suggesting the contribution of brain systems other than ToM in the comprehension of indirect speech acts. Overall, the present work highlights the importance of considering the communicative function of language in the study of its neuro-cognitive processing. In addition, the work provides valuable insights to further develop current neurobiological models of language to account for these pragmatic effects.

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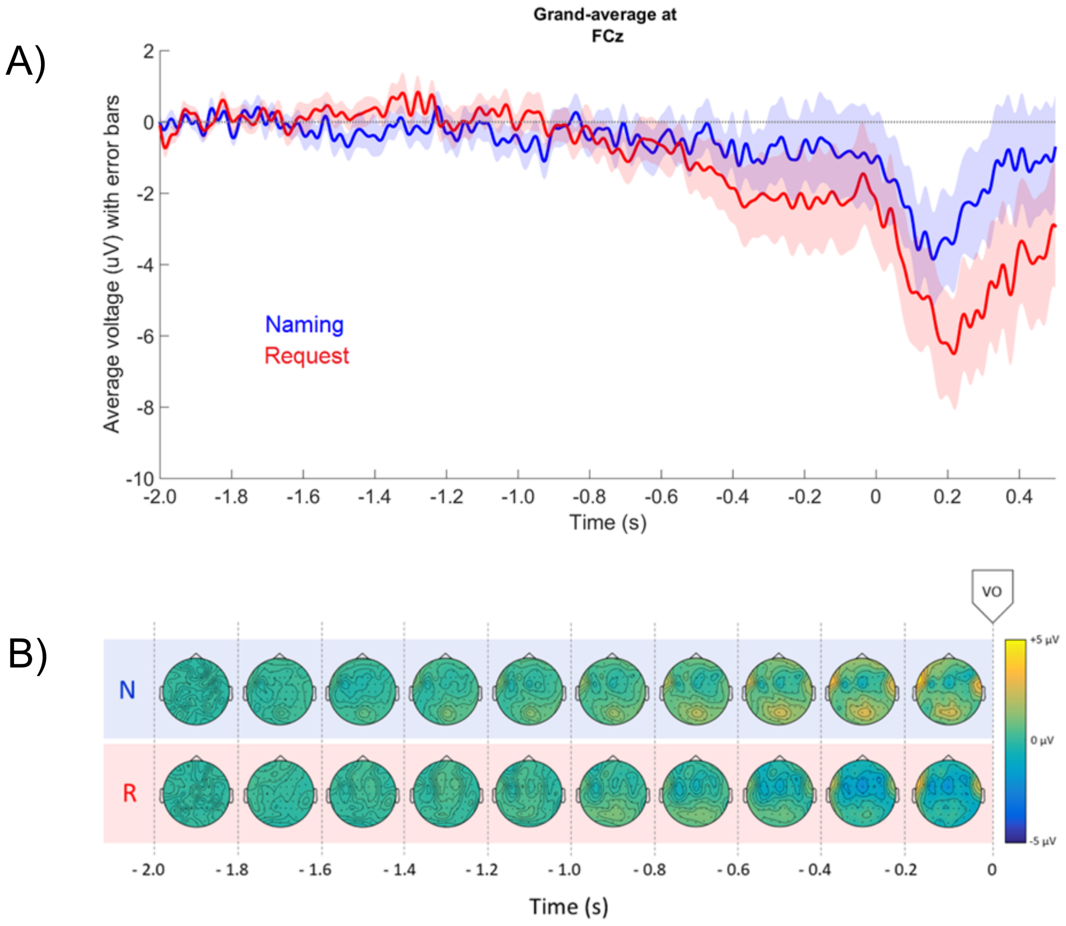
A

Supplementary Material to Chapter 2

In order to explore whether the ERP signals were affected by artifacts, we conducted an additional ERP analysis with a more conservative artifact rejection threshold (±100 µV). All other preprocessing steps remained identical to the main analysis and were performed in the same order as documented in the main article. This additional analysis resulted in a higher amount of rejected trials, and in turn more subjects had to be excluded as the trial rejections rate was high (i.e., ¿20% of trials). Therefore, this alternative analysis was conducted on N=17 subjects. To determine any differences between the two conditions, we performed an additional one-tail cluster-based permutation test on the same spatial and temporal extent (from -1000 ms to voice onset) as in the main analysis reported in the main article. The statistical test indicated a significant difference between naming and request functions ($p=0.024$, with $\alpha=0.05$), which was most pronounced in the time window going from -430 ms to -120 ms, relative to voice onset. The present result confirms the robustness of the findings reported in the main analysis, namely different neurophysiological responses for different speech act types prior to speech production, after a more stringent preprocessing and with a lower final sample size.

Figure A.1: (A) Grand average event-related potentials (ERP) with artifact rejection of ±100 μV measured prior to the onset of naming (blue) and request (red) actions with standard error of the mean (SEM) being indicated by the lighter shade of the respective color. Recordings are from the mid-fronto-central electrode FCz. The X axis represents time in seconds before and after speaking onset (voice onset, VO) and the Y axis represents the ERP amplitude in micro-Volt (μV). (B) ERP topographies for naming and request trials from -2000 ms to voice onset (VO), given as maps each displaying average potentials up to VO in time windows of 200ms. Each map shows the head and recording array from above, with the nose pointing upward.



B

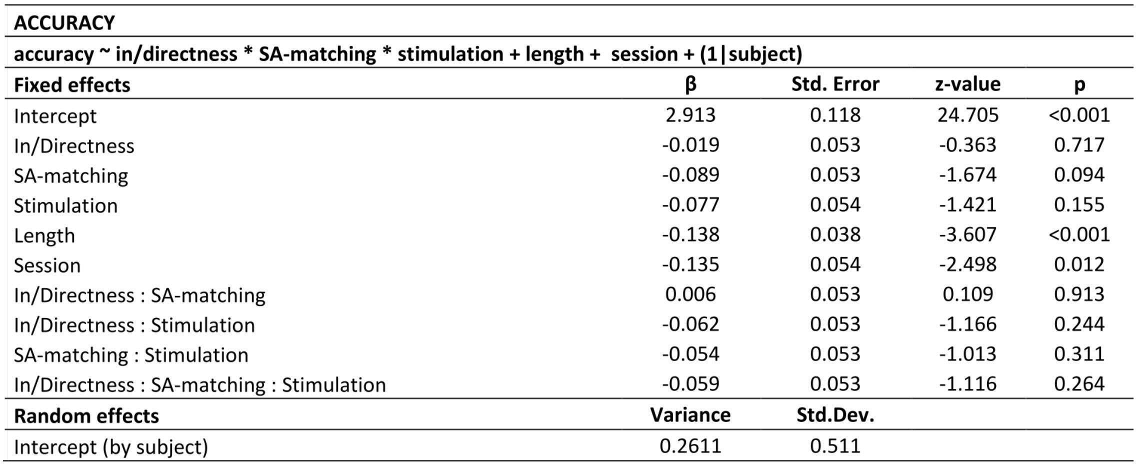
Supplementary Material to Chapter 3

B.1 Accuracy at the Pragmatic Task

As the hypothesized model (P) failed to converge for the accuracy data, a simplified model was tested, dropping the confound predictors (Pa), which however also did not converge. Thus, our final model was (Pc) with the confound predictors included, but with the random term for by-item intercepts dropped.

(P) Variable ∼ In/Directness * Stimulation * SA-matching + length + session + (1|Subject) + (1|Item)
(Pa) Variable ∼ In/Directness * Stimulation * SA-matching + (1|Subject) + (1|Item)
(Pb) Variable ∼ In/Directness * Stimulation * SA-matching + length + session + (1|Subject)

Table B.1: Fixed and random effects for the model predicting accuracy data in the Pragmatic task. Sum contrast was used for all categorical predictors (see Section 3.2.7).



ACCURACY				
accuracy ~ in/directness * SA-matching * stimulation + length + session + (1|subject)				
Fixed effects	**β**	**Std. Error**	**z-value**	**p**
Intercept	2.913	0.118	24.705	<0.001
In/Directness	-0.019	0.053	-0.363	0.717
SA-matching	-0.089	0.053	-1.674	0.094
Stimulation	-0.077	0.054	-1.421	0.155
Length	-0.138	0.038	-3.607	<0.001
Session	-0.135	0.054	-2.498	0.012
In/Directness : SA-matching	0.006	0.053	0.109	0.913
In/Directness : Stimulation	-0.062	0.053	-1.166	0.244
SA-matching : Stimulation	-0.054	0.053	-1.013	0.311
In/Directness : SA-matching : Stimulation	-0.059	0.053	-1.116	0.264
Random effects	**Variance**	**Std.Dev.**		
Intercept (by subject)	0.2611	0.511		

B.2 RTs at the Pragmatic Task

Table B.2: Fixed and random effects for the model predicting accuracy data in the Pragmatic task. Sum contrast was used for all categorical predictors (see Section 3.2.7).

RTs					
log10(RTs) ~ in/directness* SA-matching * stimulation + length + session + (1|subject) + (1|item)					
Fixed effects	**β**	**Std. Error**	**df**	**z-value**	**p**
Intercept	3.111	0.014	27.890	220.067	<0.001
In/Directness	-0.011	0.001	5678	-7.942	<0.001
SA-matching	0.002	0.004	126.600	0.582	0.562
Stimulation	0.001	0.001	5685	0.425	0.671
Length	0.020	0.003	127.200	7.946	<0.001
Session	0.015	0.001	5685	10.637	<0.001
In/Directness : SA-matching	-0.003	0.001	5678	-2.569	0.010
In/Directness : Stimulation	-0.001	0.001	5677	-0.841	0.401
SA-matching : Stimulation	-0.001	0.001	5675	-0.709	0.478
In/Directness : SA-matching : Stimulation	0.001	0.001	5677	0.837	0.403
Random effects	**Variance**	**Std.Dev.**			
Intercept (by subject)	0.001	0.037			
Intercept (by item)	0.005	0.070			
Residual	0.010	0.102			

Table B.3: Post-hoc tests on to further elucidate the lack of significant of the In/Directness * SA-matching interaction in the sham condition. Results are averaged over the levels of stimulation and session. The Kenward-Roger was used for calculating degrees of freedom. P-values are corrected for a family of 4 estimates by Tukey's HSD method. Relevant comparisons are highlighted in grey.

contrast			**estimate**	**SE**	**df**	**z.ratio**	$p_{\text{uncorrected}}$	p_{Tukey}
direct/SA-matched	-	indirect/SA-matched	-0.028	0.004	5682	-7.643	<.0001	<.0001
direct/SA-matched	-	direct/non-SA-matched	-0.003	0.008	169	-0.366	0.715	0.983
direct/SA-matched	-	indirect/non-SA-matched	-0.017	0.008	169	-2.268	0.025	0.110
indirect/SA-matched	-	direct/non-SA-matched	0.025	0.008	168	3.358	0.001	0.005
indirect/SA-matched	-	indirect/non-SA-matched	0.011	0.008	169	1.454	0.148	0.468
direct/non-SA-matched	-	indirect/non-SA-matched	-0.014	0.004	5679	-3.700	0.000	0.001

Table B.4: Post-hoc tests on to further elucidate the significant of the In/Directness * SA-matching interaction in the verum condition. Results are averaged over the levels of stimulation and session. The Kenward-Roger was used for calculating degrees of freedom. P-values are corrected for a family of 4 estimates by Tukey's HSD method. Relevant comparisons are highlighted in grey.

contrast			**estimate**	**SE**	**df**	**z.ratio**	$p_{\text{uncorrected}}$	p_{Tukey}
direct/SA-matched	-	indirect/SA-matched	-0.028	0.005	2977	-5.762	<.0001	<.0001
direct/SA-matched	-	direct/non-SA-matched	-0.002	0.008	194	-0.273	0.785	0.993
direct/SA-matched	-	indirect/non-SA-matched	-0.013	0.008	193	-1.564	0.119	0.402
indirect/SA-matched	-	direct/non-SA-matched	0.026	0.008	194	3.125	0.002	0.011
indirect/SA-matched	-	indirect/non-SA-matched	0.015	0.008	193	1.839	0.067	0.258
direct/non-SA-matched	-	indirect/non-SA-matched	-0.011	0.005	2979	-2.060	0.040	0.167

B.3 Accuracy in the Theory of Mind Task

Table B.5: Fixed and random effects for the model predicting accuracy data in the ToM task. Sum contrast was used for all categorical predictors (see Section 3.2.7).

ACCURACY				
accuracy ~ belief * desire * stimulation + length + session + (1|subject) + (1|item)				
Fixed effects	**β**	**Std. Error**	**z-value**	**p**
Intercept	2.520	0.153	16.516	<0.001
Belief	0.682	0.053	12.995	<0.001
Desire	0.401	0.053	7.636	<0.001
Stimulation	-0.020	0.054	-0.364	0.715
Session	-0.152	0.045	-3.382	0.001
Belief : Desire	0.201	0.052	3.832	<0.001
Belief : Stimulation	0.024	0.052	0.463	0.643
Desire : Stimulation	-0.014	0.052	-0.261	0.794
Belief : Desire : Stimulation	-0.057	0.052	-1.082	0.279
Random effects	**Variance**	**Std.Dev.**		
Intercept (by subject)	0.488	0.698		
Intercept (by item)	0.013	0.114		

Table B.6: Post-hoc tests on to further elucidate the marginally significant Belief * Desire interaction. Results are averaged over the levels of stimulation and session. The Kenward-Roger was used for calculating degrees of freedom. P-values are corrected for a family of 4 estimates by Tukey's HSD method. Relevant comparisons are highlighted in grey.

contrast	**estimate**	**SE**	**df**	**z.ratio**	**$p_{uncorrected}$**	**p_{Tukey}**
B+/D+ - B-/D+	1.766	0.175	Inf	10.112	<.0001	<.0001
B+/D+ - B+/D-	1.203	0.183	Inf	6.573	<.0001	<.0001
B+/D+ - B-/D-	2.166	0.171	Inf	12.65	<.0001	<.0001
B-/D+ - B+/D-	-0.563	0.122	Inf	-4.629	<.0001	<.0001
B-/D+ - B-/D-	0.4	0.102	Inf	3.908	0.0001	0.0005
B+/D- - B-/D-	0.963	0.116	Inf	8.289	<.0001	<.0001

B.4 RTs in the Theory of Mind Task

Table B.7: Post-hoc tests on to further elucidate the marginally significant Belief * Stimulation interaction. Results are averaged over the levels of Session and Desire. The Kenward-Roger was used for calculating degrees of freedom. P-values are corrected for a family of 4 estimates by Tukey's HSD method. Relevant comparisons are highlighted in grey.

contrast			estimate	SE	df	z.ratio	$p_{uncorrected}$	p_{Tukey}
B+/D+	-	B-/D+	-0.155	0.005	5362.000	-29.759	<.0001	<.0001
B+/D+	-	B+/D-	-0.142	0.005	5285.000	-27.634	<.0001	<.0001
B+/D+	-	B-/D-	-0.195	0.005	5319.000	-36.995	<.0001	<.0001
B-/D+	-	B+/D-	0.013	0.005	5330.000	2.461	0.014	0.066
B-/D+	-	B-/D-	-0.040	0.005	5335.000	-7.478	<.0001	<.0001
B+/D-	-	B-/D-	-0.053	0.005	5361.000	-10.025	<.0001	<.0001

Table B.8: Post-hoc tests on to further elucidate the marginally significant Belief * Desire * Stimulation interaction. Results are averaged over the levels of Session. The Kenward-Roger was used for calculating degrees of freedom. P-values are corrected for a family of 8 estimates by Tukey's HSD method. Relevant comparisons are highlighted in grey.

contrast			estimate	SE	df	z.ratio	$p_{uncorrected}$	p_{Tukey}
B+/D+/sham	-	B-/D+/sham	-0.165	0.008	5361	-21.688	<.0001	<.0001
B+/D+/sham	-	B+/D-/sham	-0.149	0.007	5331	-20.002	<.0001	<.0001
B+/D+/sham	-	B-/D-/sham	-0.199	0.008	5321	-25.919	<.0001	<.0001
B+/D+/sham	-	B+/D+/verum	0.008	0.007	5367	1.133	0.257	0.950
B+/D+/sham	-	B-/D+/verum	-0.137	0.007	5366	-18.518	<.0001	<.0001
B+/D+/sham	-	B+/D-/verum	-0.127	0.007	5355	-17.213	<.0001	<.0001
B+/D+/sham	-	B-/D-/verum	-0.183	0.007	5367	-24.399	<.0001	<.0001
B-/D+/sham	-	B+/D-/sham	0.015	0.008	5338	2.019	0.044	0.469
B-/D+/sham	-	B-/D-/sham	-0.035	0.008	5328	-4.457	<.0001	0.0002
B-/D+/sham	-	B+/D+/verum	0.173	0.007	5368	23.285	<.0001	<.0001
B-/D+/sham	-	B-/D+/verum	0.027	0.008	5364	3.633	0.000	0.007
B-/D+/sham	-	B+/D-/verum	0.038	0.008	5366	5.049	<.0001	<.0001
B-/D+/sham	-	B-/D-/verum	-0.018	0.008	5366	-2.366	0.018	0.258
B+/D-/sham	-	B-/D-/sham	-0.050	0.008	5360	-6.538	<.0001	<.0001
B+/D-/sham	-	B+/D+/verum	0.157	0.007	5353	21.607	<.0001	<.0001
B+/D-/sham	-	B-/D+/verum	0.012	0.007	5362	1.627	0.104	0.734
B+/D-/sham	-	B+/D-/verum	0.023	0.007	5366	3.063	0.002	0.046
B+/D-/sham	-	B-/D-/verum	-0.033	0.007	5367	-4.46	<.0001	0.0002
B-/D-/sham	-	B+/D+/verum	0.208	0.008	5348	27.6	<.0001	<.0001
B-/D-/sham	-	B-/D+/verum	0.062	0.008	5360	8.147	<.0001	<.0001
B-/D-/sham	-	B+/D-/verum	0.073	0.008	5367	9.589	<.0001	<.0001
B-/D-/sham	-	B-/D-/verum	0.017	0.008	5366	2.188	0.029	0.359
B+/D+/verum	-	B-/D+/verum	-0.145	0.007	5360	-20.392	<.0001	<.0001
B+/D+/verum	-	B+/D-/verum	-0.135	0.007	5361	-19.12	<.0001	<.0001
B+/D+/verum	-	B-/D-/verum	-0.191	0.007	5361	-26.518	<.0001	<.0001
B-/D+/verum	-	B+/D-/verum	0.010	0.007	5362	1.451	0.147	0.833
B-/D+/verum	-	B-/D-/verum	-0.045	0.007	5360	-6.186	<.0001	<.0001
B+/D-/verum	-	B-/D-/verum	-0.056	0.007	5360	-7.681	<.0001	<.0001

C

Supplementary Material to Chapter 4

C.1 Rating's summary and variability

Table C.1: By-item means, standard deviations (SD) and standard error of the mean (SEM) for the ratings of Function (FUN-R), Coherence (COH-R), Directness (DIR-R), Predictability (PRE-R), Semantic Similarity (SSI-R) and Certainty (CER-R) averaged separately first by item and then by SA-matching, In/Directness and Polarity. Mean of SD indicates the average of the standard deviation across items, in each condition. It is an indicator of the consistency of the ratings given by the subjects.

Variable	**SA-matching**	**Pragmtics**	**Polarity**	**Mean**	**SD**	**SEM**	**Mean of SD**
FUN-R	SA-matched	direct	no	1.53	0.46	0.08	0.94
			yes	6.52	0.33	0.06	0.82
		indirect	no	2.04	0.46	0.08	1.13
			yes	5.84	0.48	0.08	1.06
	non-SA-matched	direct	no	1.55	0.31	0.05	1.01
			yes	6.49	0.31	0.05	0.79
		indirect	no	1.93	0.34	0.06	1.09
			yes	5.72	0.49	0.09	1.10
COH-R	SA-matched	direct	no	5.97	0.66	0.11	1.12
			yes	5.98	0.57	0.09	1.15
		indirect	no	4.15	1.02	0.17	1.52
			yes	3.92	1.09	0.18	1.50
	non-SA-matched	direct	no	5.84	0.72	0.13	1.21
			yes	5.79	0.61	0.11	1.20
		indirect	no	4.43	0.97	0.17	1.39
			yes	3.27	0.72	0.13	1.43
DIR-R	SA-matched	direct	no	5.60	0.76	0.13	1.39
			yes	5.87	0.64	0.11	1.19
		indirect	no	3.67	0.91	0.15	1.61
			yes	3.65	1.04	0.17	1.62
	non-SA-matched	direct	no	5.55	0.83	0.14	1.35
			yes	5.65	0.64	0.11	1.28
		indirect	no	3.88	0.96	0.17	1.57
			yes	3.04	0.59	0.10	1.47
PRE-R	SA-matched	direct	no	5.58	0.63	0.10	1.36
			yes	5.67	0.50	0.08	1.40
		indirect	no	4.51	0.86	0.14	1.65
			yes	4.29	0.93	0.16	1.61
	non-SA-matched	direct	no	5.41	0.71	0.12	1.49
			yes	5.50	0.59	0.10	1.41
		indirect	no	4.89	0.67	0.12	1.55
			yes	3.80	0.75	0.13	1.62
SSI-R	SA-matched	direct	no	5.68	0.58	0.10	1.38
			yes	6.04	0.48	0.08	1.12
		indirect	no	4.09	0.78	0.13	1.65
			yes	4.09	0.97	0.16	1.62
	non-SA-matched	direct	no	5.56	0.57	0.10	1.51
			yes	5.94	0.47	0.08	1.13
		indirect	no	4.37	0.78	0.14	1.63
			yes	3.79	0.67	0.12	1.61
CER-R	SA-matched	direct	no	3.64	0.32	0.32	0.57
			yes	3.59	0.26	0.26	0.66
		indirect	no	3.09	0.46	0.46	0.87
			yes	2.90	0.45	0.45	0.95
	non-SA-matched	direct	no	3.57	0.28	0.28	0.67
			yes	3.55	0.24	0.24	0.68
		indirect	no	3.20	0.34	0.34	0.79
			yes	2.84	0.40	0.40	0.96

C.2 Post-hoc tests after LMM

Table C.2: Results of the post-hoc tests on the three-way Directness by Polarity by SA-matching interaction effect on Directness (DIR-R) ratings. p-values are corrected with Tuckey's HSD. Single-degree-of-difference contrasts are indicated in gray.

Directness (DIR-R)					
contrast	estimate	SE	df	t-ratio	*p*
direct, SA-matched, no - indirect, SA-matched, no	1.93	0.06	7559	30.10	<.0001
direct, SA-matched, no - direct, non-SA-matched, no	0.05	0.17	157	0.30	1
direct, SA-matched, no - indirect, non-SA-matched, no	1.72	0.17	157	10.32	<.0001
direct, SA-matched, no - direct, SA-matched, yes	-0.27	0.16	157	-1.67	0.708
direct, SA-matched, no - indirect, SA-matched, yes	1.95	0.16	157	11.98	<.0001
direct, SA-matched, no - direct, non-SA-matched, yes	-0.05	0.17	157	-0.27	1
direct, SA-matched, no - indirect, non-SA-matched, yes	2.56	0.17	157	15.36	<.0001
indirect, SA-matched, no - direct, non-SA-matched, no	-1.88	0.17	157	-11.29	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, no	-0.21	0.17	157	-1.27	0.907
indirect, SA-matched, no - direct, SA-matched, yes	-2.20	0.16	157	-13.52	<.0001
indirect, SA-matched, no - indirect, SA-matched, yes	0.02	0.16	157	0.13	1
indirect, SA-matched, no - direct, non-SA-matched, yes	-1.98	0.17	157	-11.87	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, yes	0.63	0.17	157	3.76	0.0056
direct, non-SA-matched, no - indirect, non-SA-matched, no	1.67	0.07	7559	24.90	<.0001
direct, non-SA-matched, no - direct, SA-matched, yes	-0.32	0.17	157	-1.93	0.531
direct, non-SA-matched, no - indirect, SA-matched, yes	1.90	0.17	157	11.42	<.0001
direct, non-SA-matched, no - direct, non-SA-matched, yes	-0.10	0.17	157	-0.56	0.9993
direct, non-SA-matched, no - indirect, non-SA-matched, yes	2.51	0.17	157	14.74	<.0001
indirect, non-SA-matched, no - direct, SA-matched, yes	-1.99	0.17	157	-11.95	<.0001
indirect, non-SA-matched, no - indirect, SA-matched, yes	0.23	0.17	157	1.40	0.8564
indirect, non-SA-matched, no - direct, non-SA-matched, yes	-1.77	0.17	157	-10.37	<.0001
indirect, non-SA-matched, no - indirect, non-SA-matched, yes	0.84	0.17	157	4.93	0.0001
direct, SA-matched, yes - indirect, SA-matched, yes	2.23	0.06	7559	34.66	<.0001
direct, SA-matched, yes - direct, non-SA-matched, yes	0.23	0.17	157	1.36	0.8734
direct, SA-matched, yes - indirect, non-SA-matched, yes	2.83	0.17	157	16.99	<.0001
indirect, SA-matched, yes - direct, non-SA-matched, yes	-2.00	0.17	157	-11.99	<.0001
indirect, SA-matched, yes - indirect, non-SA-matched, yes	0.61	0.17	157	3.64	0.0087
direct, non-SA-matched, yes - indirect, non-SA-matched, yes	2.61	0.07	7559	38.85	<.0001

Table C.3: Results of the post-hoc tests on the three-way Directness by Polarity by SA-matching interaction effect on Coherence (COH-R) ratings. p-values are corrected with Tuckey's HSD. Single-degree-of-difference contrasts are indicated in gray.

Coherence (COH-R)					
contrast	estimate	SE	df	t-ratio	*p*
direct, SA-matched, no - indirect, SA-matched, no	1.82	0.06	7559	30.10	<.0001
direct, SA-matched, no - direct, non-SA-matched, no	0.12	0.16	155	0.75	0.9951
direct, SA-matched, no - indirect, non-SA-matched, no	1.54	0.16	155	9.40	<.0001
direct, SA-matched, no - direct, SA-matched, yes	-0.02	0.16	155	-0.10	1
direct, SA-matched, no - indirect, SA-matched, yes	2.05	0.16	155	12.80	<.0001
direct, SA-matched, no - direct, non-SA-matched, yes	0.18	0.16	155	1.10	0.9565
direct, SA-matched, no - indirect, non-SA-matched, yes	2.69	0.16	155	16.47	<.0001
indirect, SA-matched, no - direct, non-SA-matched, no	-1.69	0.16	155	-10.36	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, no	-0.28	0.16	155	-1.71	0.6842
indirect, SA-matched, no - direct, SA-matched, yes	-1.83	0.16	155	-11.46	<.0001
indirect, SA-matched, no - indirect, SA-matched, yes	0.23	0.16	155	1.44	0.8376
indirect, SA-matched, no - direct, non-SA-matched, yes	-1.64	0.16	155	-10.01	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, yes	0.88	0.16	155	5.36	<.0001
direct, non-SA-matched, no - indirect, non-SA-matched, no	1.41	0.06	7559	22.44	<.0001
direct, non-SA-matched, no - direct, SA-matched, yes	-0.14	0.16	155	-0.85	0.9898
direct, non-SA-matched, no - indirect, SA-matched, yes	1.92	0.16	155	11.76	<.0001
direct, non-SA-matched, no - direct, non-SA-matched, yes	0.06	0.17	155	0.34	1
direct, non-SA-matched, no - indirect, non-SA-matched, yes	2.57	0.17	155	15.39	<.0001
indirect, non-SA-matched, no - direct, SA-matched, yes	-1.55	0.16	155	-9.50	<.0001
indirect, non-SA-matched, no - indirect, SA-matched, yes	0.51	0.16	155	3.11	0.0447
indirect, non-SA-matched, no - direct, non-SA-matched, yes	-1.36	0.17	155	-8.13	<.0001
indirect, non-SA-matched, no - indirect, non-SA-matched, yes	1.16	0.17	155	6.92	<.0001
direct, SA-matched, yes - indirect, SA-matched, yes	2.06	0.06	7559	34.17	<.0001
direct, SA-matched, yes - direct, non-SA-matched, yes	0.20	0.16	155	1.20	0.9324
direct, SA-matched, yes - indirect, non-SA-matched, yes	2.71	0.16	155	16.57	<.0001
indirect, SA-matched, yes - direct, non-SA-matched, yes	-1.87	0.16	155	-11.42	<.0001
indirect, SA-matched, yes - indirect, non-SA-matched, yes	0.65	0.16	155	3.96	0.0029
direct, non-SA-matched, yes - indirect, non-SA-matched, yes	2.51	0.06	7559	39.88	<.0001

Table C.4: Results of the post-hoc tests on the three-way Directness by Polarity by SA-matching interaction effect on Predictability (PRE-R) ratings. p-values are corrected with Tuckey's HSD. Single-degree-of-difference contrasts are indicated in gray.

Predictability (PRE-R)					
contrast	estimate	SE	df	t-ratio	*p*
direct, SA-matched, no - indirect, SA-matched, no	1.07	0.07	7559	16.37	<.0001
direct, SA-matched, no - direct, non-SA-matched, no	0.17	0.15	164	1.11	0.9542
direct, SA-matched, no - indirect, non-SA-matched, no	0.69	0.15	164	4.51	0.0003
direct, SA-matched, no - direct, SA-matched, yes	-0.09	0.15	164	-0.61	0.9987
direct, SA-matched, no - indirect, SA-matched, yes	1.29	0.15	164	8.63	<.0001
direct, SA-matched, no - direct, non-SA-matched, yes	0.08	0.15	164	0.55	0.9994
direct, SA-matched, no - indirect, non-SA-matched, yes	1.78	0.15	164	11.65	<.0001
indirect, SA-matched, no - direct, non-SA-matched, no	-0.90	0.15	164	-5.90	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, no	-0.38	0.15	164	-2.50	0.2039
indirect, SA-matched, no - direct, SA-matched, yes	-1.16	0.15	164	-7.77	<.0001
indirect, SA-matched, no - indirect, SA-matched, yes	0.22	0.15	164	1.47	0.8224
indirect, SA-matched, no - direct, non-SA-matched, yes	-0.98	0.15	164	-6.46	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, yes	0.71	0.15	164	4.65	0.0002
direct, non-SA-matched, no - indirect, non-SA-matched, no	0.52	0.07	7559	7.60	<.0001
direct, non-SA-matched, no - direct, SA-matched, yes	-0.26	0.15	164	-1.71	0.6828
direct, non-SA-matched, no - indirect, SA-matched, yes	1.12	0.15	164	7.33	<.0001
direct, non-SA-matched, no - direct, non-SA-matched, yes	-0.09	0.16	164	-0.55	0.9994
direct, non-SA-matched, no - indirect, non-SA-matched, yes	1.61	0.16	164	10.32	<.0001
indirect, non-SA-matched, no - direct, SA-matched, yes	-0.78	0.15	164	-5.11	<.0001
indirect, non-SA-matched, no - indirect, SA-matched, yes	0.60	0.15	164	3.94	0.003
indirect, non-SA-matched, no - direct, non-SA-matched, yes	-0.60	0.16	164	-3.88	0.0038
indirect, non-SA-matched, no - indirect, non-SA-matched, yes	1.09	0.16	164	6.99	<.0001
direct, SA-matched, yes - indirect, SA-matched, yes	1.38	0.07	7559	21.13	<.0001
direct, SA-matched, yes - direct, non-SA-matched, yes	0.17	0.15	164	1.15	0.9453
direct, SA-matched, yes - indirect, non-SA-matched, yes	1.87	0.15	164	12.25	<.0001
indirect, SA-matched, yes - direct, non-SA-matched, yes	-1.20	0.15	164	-7.89	<.0001
indirect, SA-matched, yes - indirect, non-SA-matched, yes	0.49	0.15	164	3.21	0.0335
direct, non-SA-matched, yes - indirect, non-SA-matched, yes	1.69	0.07	7559	24.85	<.0001

Table C.5: Results of the post-hoc tests on the three-way Directness by Polarity by SA-matching interaction effect on Semantic Similarity (SSI-R) ratings. p-values are corrected with Tuckey's HSD. Single-degree-of-difference contrasts are indicated in gray.

Semantic Similarity (SSI-R)					
contrast	estimate	SE	df	t-ratio	*p*
direct, SA-matched, no - indirect, SA-matched, no	1.59	0.06	7559	25.37	<.0001
direct, SA-matched, no - direct, non-SA-matched, no	0.12	0.14	170	0.86	0.9893
direct, SA-matched, no - indirect, non-SA-matched, no	1.31	0.14	170	9.65	<.0001
direct, SA-matched, no - direct, SA-matched, yes	-0.37	0.13	170	-2.77	0.1089
direct, SA-matched, no - indirect, SA-matched, yes	1.59	0.13	170	12.01	<.0001
direct, SA-matched, no - direct, non-SA-matched, yes	-0.26	0.14	170	-1.92	0.5408
direct, SA-matched, no - indirect, non-SA-matched, yes	1.88	0.14	170	13.91	<.0001
indirect, SA-matched, no - direct, non-SA-matched, no	-1.47	0.14	170	-10.86	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, no	-0.28	0.14	170	-2.06	0.445
indirect, SA-matched, no - direct, SA-matched, yes	-1.95	0.13	170	-14.75	<.0001
indirect, SA-matched, no - indirect, SA-matched, yes	0.00	0.13	170	0.03	1
indirect, SA-matched, no - direct, non-SA-matched, yes	-1.84	0.14	170	-13.63	<.0001
indirect, SA-matched, no - indirect, non-SA-matched, yes	0.30	0.14	170	2.20	0.3561
direct, non-SA-matched, no - indirect, non-SA-matched, no	1.19	0.07	7559	18.24	<.0001
direct, non-SA-matched, no - direct, SA-matched, yes	-0.48	0.14	170	-3.57	0.0108
direct, non-SA-matched, no - indirect, SA-matched, yes	1.47	0.14	170	10.89	<.0001
direct, non-SA-matched, no - direct, non-SA-matched, yes	-0.38	0.14	170	-2.72	0.1249
direct, non-SA-matched, no - indirect, non-SA-matched, yes	1.77	0.14	170	12.78	<.0001
indirect, non-SA-matched, no - direct, SA-matched, yes	-1.67	0.14	170	-12.36	<.0001
indirect, non-SA-matched, no - indirect, SA-matched, yes	0.28	0.14	170	2.09	0.4259
indirect, non-SA-matched, no - direct, non-SA-matched, yes	-1.57	0.14	170	-11.33	<.0001
indirect, non-SA-matched, no - indirect, non-SA-matched, yes	0.58	0.14	170	4.17	0.0012
direct, SA-matched, yes - indirect, SA-matched, yes	1.96	0.06	7559	31.31	<.0001
direct, SA-matched, yes - direct, non-SA-matched, yes	0.11	0.14	170	0.79	0.9932
direct, SA-matched, yes - indirect, non-SA-matched, yes	2.25	0.14	170	16.63	<.0001
indirect, SA-matched, yes - direct, non-SA-matched, yes	-1.85	0.14	170	-13.66	<.0001
indirect, SA-matched, yes - indirect, non-SA-matched, yes	0.29	0.14	170	2.17	0.3739
direct, non-SA-matched, yes - indirect, non-SA-matched, yes	2.14	0.07	7559	32.83	<.0001

Table C.6: Results of the post-hoc tests on the three-way Directness by Polarity by SA-matching interaction effect on Certainty (CER-R) ratings. p-values are corrected with Tuckey's HSD. Single-degree-of-difference contrasts are indicated in gray.

Certainty (CER-R)					
contrast	estimate	SE	df	t-ratio	*p*
direct, no - indirect, no	0.46	0.02	7561	19.51	<.0001
direct, no - direct, yes	0.03	0.05	170	0.65	0.9155
direct, no - indirect, yes	0.73	0.05	170	14.15	<.0001
indirect, no - direct, yes	-0.43	0.05	170	-8.27	<.0001
indirect, no - indirect, yes	0.27	0.05	170	5.24	<.0001
direct, yes - indirect,yes	0.70	0.02	7561	29.55	<.0001

C.3 Differential score analysis between dimensions

Another approach to test the hypothesis that the dimensions of Directness, Certainty, Predictability, Semantic Similarity and Coherence are associated with one another is to seek out some direct-indirect item pairs that will still be dissimilar with respect to their Directness, while remaining matched on some of the other dimensions. Note that, as opposed to the previous simple correlation analysis between dimensions, the direct and indirect items are not considered as independent any longer, but jointly. Thus, for each scale, we computed the difference between the direct and the indirect score, which is what we will call the differential scores (ΔCOH-R, ΔDIR-R, ΔSSI-R, ΔPRE-R, ΔCER-R). These differential scores were correlated with each other pairwise. Here again, statistical testing of the correlations was Bonferroni corrected (for 10 comparisons). We therefore report corrected p-values. Additionally, we attempted to identify item pairs that could be matched on one of the dimensions of COH-R, PRE-R, SSI-R or CER-R while still differing on the dimension of DIR-R. An item pair was considered to be matched on one dimension if $|\Delta| \leq 0.5$ for that dimension. A smaller threshold of $|\Delta| \leq 0.25$ was applied to the CER-R dimension as this dimension had a maximum possible range that was half-smaller compared to all other measured dimensions. Conversely, the dimension of Directness was considered as being sufficiently different within an item pair if ΔDIR-R ≥ 1.

The analysis of the relationship between differential scores within direct-indirect pairs of items also revealed relevant relationships across variables. First, visual exploration confirmed that for each pair of variables, the large majority of the subtractions produced positive values, thus confirming higher ratings for direct than indirect speech acts (COH-R: 97%; PRE-R: 91%; SSI-R: 98%; CER-R: 92%). In the case of the Directness rating, all items had grater ratings in the direct than in the indirect form, as they had been pre-selected for this criterion (see Section 4.2.4). Furthermore, figure C.1 shows that, for each paiwise correlation, if the direct item scored higher on a given variable than its indirect counterpart, this was also so for the second variable (see dots in the green quadrants). In the few rare cases where direct speech acts received a lower rating than their direct counterpart in a dimension, this was consistently so across the other rating dimensions (see dots in the red quadrant). Furthermore, all the bivariate Pearson correlations were highly significant ($p \leq 0.001$) with Pearson coefficients above 0.70 (Figure C.1). This indicated that whenever the distance between direct and indirect items increased along one dimension, it would also tend to increase on any of the other considered dimensions.

Close item-by-item inspection showed that some exceptions could be found to this pattern (see tables C.7 and C.8 for a full list). In the SA-matched set, 12 out of 72 item pairs (17%) were found which were differing on the Directness dimension while still being matched on at least one further dimension. Of these 12 item pairs, 8 where matched for one further variable, 3 for two further variables, 1 for three and 0 for all four further variables. In the non-SA-matched set, 9 out of 66 item pairs (14%) were identified with the same criteria. Of these 9 item pairs, 6 where matched for one further variable, 3 for two further variables, 0 for three and 0 for all four further variables.

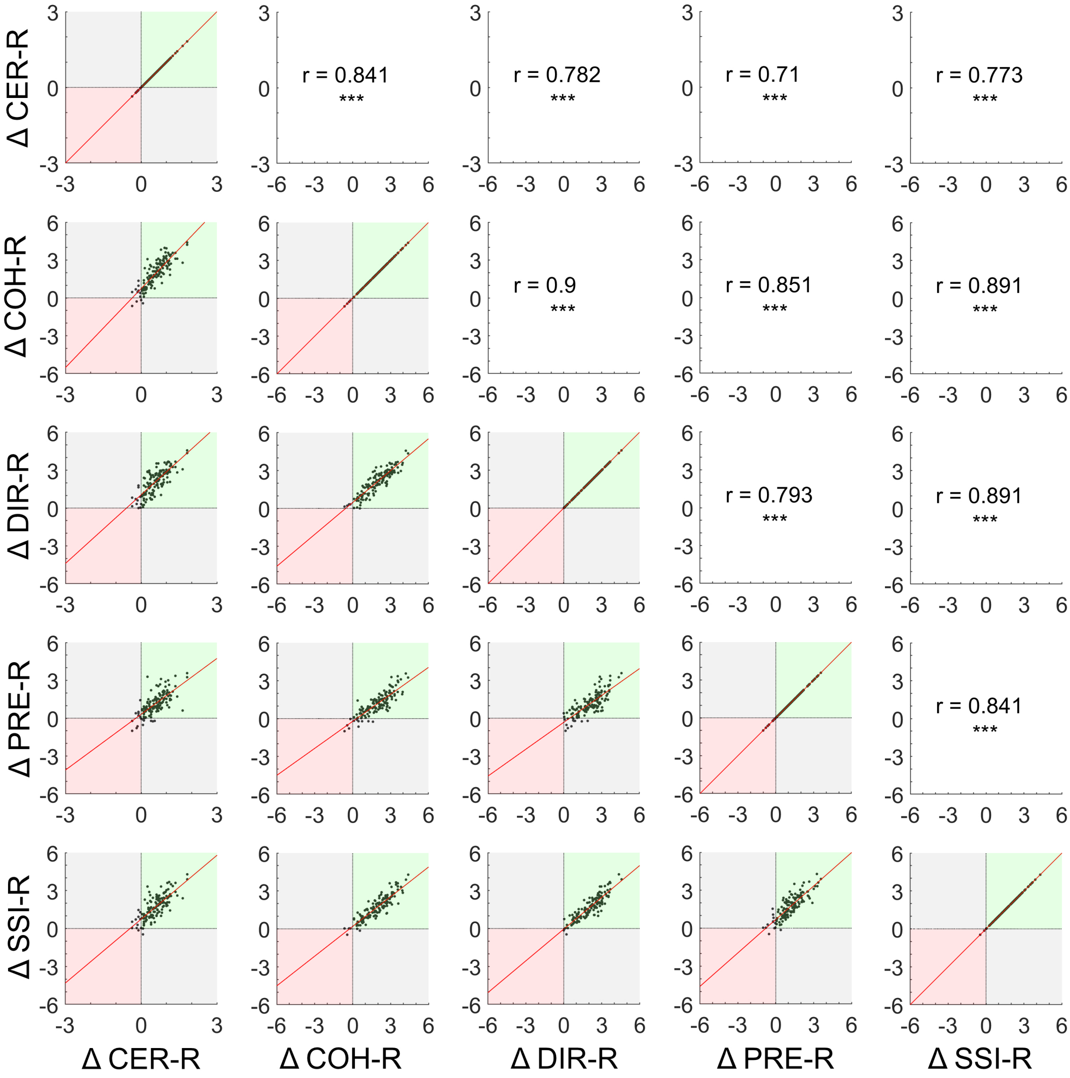


Figure C.1: Correlation matrix shown for the following differential scores: differential certainty (ΔCER-R), differential coherence (ΔCOH-R), differential directness (ΔDIR-R), differential predictability (ΔPRE-R) and differential semantic similarity to the question (ΔSSI-R). Again, the plots below the diagonal show the scatter plot displaying the relationship between pairs of variables, together with the regression line in red. Each observation represents a direct-indirect item pair and its average differential score on two given dimensions. Each scatter plot is further divided into four quadrants. The green quadrant encompasses the item pairs where the direct items scored higher than its indirect counterpart in both dimensions. The gray quadrants encompass the areas where the direct item scored lower than the indirect one only on either one of the two dimensions. The red quadrant encompasses the item pairs where for both dimensions the direct item scored lower than its indirect counterpart. The plots above the diagonal show the respective R coefficient and significance level after correction for multiple comparisons (* = $p<0.05$, ** = $p<0.01$, *** = $p< 0.001$).

Table C.7: Subset of experimental item pairs from the SA-matched Set where the direct item was rated as more direct than the indirect counterpart (grey column), while at least one further dimension was matched based on the criteria specified in the Results section. For each item pair, the direct context (DIR), indirect context (INDIR) and the critical reply (CRIT) are reported. The items are listed together with their differential scores for each dimension: differential certainty (ΔCER-R), differential coherence (ΔCOH-R), differential directness (ΔDIR-R), differential predictability (ΔPRE-R) and differential semantic similarity to the question (ΔSSI-R). The asterisks next to the values indicate the dimensions for which the specific item pair was considered to be matched.

stimID (direct)	stimID (indirect)	Direct-Indirect stimuli pairs	Expected response	Δ COH-R	Δ DIR-R	Δ PRE-R	Δ SSI-R	Δ CER-R
1117	1217	DIR: 'Does your birthday party take place tomorrow?' INDIR: 'Have you failed the exam?' CRIT: 'I am celebrating tonight.'	no	3.07	2.86	3.29	3.32	0.25*
1120	1220	DIR: 'Is this area popular for something?' INDIR: 'Are there big waves here?' CRIT: 'The region is famous for surfing.'	yes	1.68	2.43	0.46*	1.68	0.39
1124	1224	DIR: 'Are you finished working on your data?' INDIR: 'Did you present your data at the meeting?' CRIT: 'I am still analyzing it.'	no	0.79	1.79	0.75	1.00	0.11*
1125	1225	DIR: 'Are there many pandas left in the world?' INDIR: 'Is it legal to hunt pandas?' CRIT: 'They are an endangered species.'	no	0.96	1.64	0.21*	1.46	-0.11*
1128	1228	DIR: 'Did you use to have long hair?' INDIR: 'Did you get your hair cut?' CRIT: 'My hair was way too long.'	yes	1.18	1.14	0.36*	1.14	0.11*
1135	1235	DIR: 'Are we all here?' INDIR: 'Are we ready to go?' CRIT: 'Mark is still missing.'	no	1.29	1.18	0.18*	1.29	0.32
1139	1239	DIR: 'Is someone taking care of their house?' INDIR: 'Is their house always so tidy?' CRIT: 'They have domestics.'	yes	1.39	2.39	0.93	1.07	0.11*
1141	1241	DIR: 'Does he own many books?' INDIR: 'Does he have a passion for history?' CRIT: 'His house is full of history books.'	yes	0.86	1.21	0.54	0.54	0.11*
1144	1244	DIR: 'Do you have two weeks of holiday?' INDIR: 'Will you take a two weeks trip?' CRIT: 'I only have one week off work.'	no	0.39*	1.18	0.07*	0.57	0.18*
1157	1257	DIR: 'Was this artist still alive in the 80s?' INDIR: 'Was this artwork created by him in 1981?' CRIT: 'He was already dead by then.'	no	0.57	1.04	0.71	1.14	0.04*
1165	1265	DIR: 'Is she out on the tennis field?' INDIR: 'Is she dressed for the tennis game?' CRIT: 'She has just got into the changing room.'	no	0.79	1.04	0.29*	0.46*	0.39
1166	1266	DIR: 'Did he get the money back?' INDIR: 'Did he settle the lawsuit?' CRIT: 'He was compensated.'	yes	0.71	1.36	0.93	0.96	0.21*

Table C.8: Subset of experimental item pairs from the non-SA-matched Set where the direct item was rated as more direct than the indirect counterpart (grey column), while at least one further dimension was matched based on the criteria specified above. For each item pair, the direct context (DIR), indirect context (INDIR) and the critical reply (CRIT) are reported. The items are listed together with their differential scores for each dimension: differential certainty (ΔCER-R), differential coherence (ΔCOH-R), differential directness (ΔDIR-R), differential predictability (ΔPRE-R) and differential semantic similarity to the question (ΔSSI-R). The asterisks next to the values indicate the dimensions for which the specific item pair was considered to be matched.

stimID (direct)	stimID (indirect)	Direct-Indirect stimuli pairs	Expected response	Δ COH-R	Δ DIR-R	Δ PRE-R	Δ SSI-R	Δ CER-R
2103	2203	DIR: 'Is it cold in your village?' INDIR: 'Shall I close the window?' CRIT: 'It is quite chilly.'	yes	1.61	2.89	1.21	2.00	0.25*
2108	2208	DIR: Is it cold outside?' INDIR: 'Do you need a coat?' CRIT: 'It is minus 20 degrees.'	yes	2.36	2.36	0.82	2.29	0.14*
2116	2216	DIR: 'Did you watch "Titanic" yesterday?' INDIR: 'Shall we watch "Titanic" tonight?' CRIT: 'I watched it last month. '	no	1.25	1.89	-0.21	1.07	0.39
2118	2218	DIR: 'Do you practise Hinduism?' INDIR: 'Do you want some pork?' CRIT: 'I am actually a Muslim.'	no	0.86	1.68	0.54	0.82	0.18*
2125	2225	DIR: 'Are you free of any chronic disease?' INDIR: 'Do you want some cake?' CRIT: 'I am actually diabetic.'	no	1.96	2.00	1.29	1.29	0.25*
2138	2238	DIR: 'Is the passport necessary for taking the plane?' INDIR: 'Shall I pack your passport?' CRIT: 'I understand everything now.'	no	0.68	1.07	0.04*	0.61	0.18*
2155	2255	DIR: 'Are you still confused about it?' INDIR: 'Shall I explain it to you again?' CRIT: 'I understand everything now.'	no	0.71	1.04	0.11*	0.79	0.11*
2162	2262	DIR: 'Did your lips get damaged with this wind?' INDIR: 'Do you want some lip balm?' CRIT: 'My lips are all chapped.'	yes	1.36	1.79	0.50*	0.93	-0.11*
2163	2263	DIR: 'Are you doing the afternoon shift tomorrow?' INDIR: 'Are you joining for drinks tonight?' CRIT: 'I am working early tomorrow morning.'	no	1.61	1.43	-0.25*	1.54	0.46

C.4 Rating as a function of exposure to the stimuli

In the present study, the various assessed dimensions could have been susceptible of being affected by the number of exposures to the stimuli. Our data set in fact allows us to test this hypothesis. Indeed, the order of blocks (and thus of ratings) was randomized across subjects, meaning that different subjects rated each property after different degrees of exposure to the stimuli. For instance, a hypothetical subject x might have rated Coherence in the first experimental block, therefore without having any previous exposure to the stimuli. But a different hypothetical subject y might have had the Coherence rating in the 4th block and therefore after several exposures to the stimulus. Therefore, we checked whether adding the block order of each individual rating (factor "exposure") as a predictor to the winning model would significantly increase model fit.

Coherence (COH-R)

(W) COH-R ~ In/Directness * Polarity * SA-matching + (1|Subject) + (1|Item)
(A) COH-R ~ In/Directness * Polarity * SA-matching + exposure + (1|Subject) + (1|Item)
(B) COH-R ~ In/Directness * Polarity * SA-matching * exposure + (1|Subject) + (1|Item)

Neither model A ($\chi^2(1)=0$, p=1) nor model B ($\chi^2(8)=0$, p=1) were better than the original winning model. The rated Coherence was therefore not affected by exposure to the stimuli.

Directness (DIR-R)

(W) DIR-R ~ In/Directness * Polarity * SA-matching + (1|Subject) + (1|Item)
(A) DIR-R ~ In/Directness * Polarity * SA-matching + exposure + (1|Subject) + (1|Item)
(B) DIR-R ~ In/Directness * Polarity * SA-matching * exposure + (1|Subject) + (1|Item)

Neither model A ($\chi^2(1)=0$, p=1) nor model B ($\chi^2(8)=0$, p=1) were better than the original winning model. The rated Directness was therefore not affected by exposure to the stimuli.

Predictability (PRE-R)

(W) PRE-R ~ In/Directness * Polarity * SA-matching + (1|Subject) + (1|Item)
(A) PRE-R ~ In/Directness * Polarity * SA-matching + exposure + (1|Subject) + (1|Item)
(B) PRE-R ~ In/Directness * Polarity * SA-matching * exposure + (1|Subject) + (1|Item)

Neither model A ($\chi^2(1)=2.370$, p=0.124) nor model B ($\chi^2(8)=0$, p=1) were better than the original winning model. The rated Predictability was therefore not affected by exposure to the stimuli.

Semantic Similarity (SSI-R)

(W) SSI-R ~ In/Directness * Polarity * SA-matching + (1|Subject) + (1|Item)
(A) SSI-R ~ In/Directness * Polarity * SA-matching + exposure + (1|Subject) + (1|Item)
(B) SSI-R ~ In/Directness * Polarity * SA-matching * exposure + (1|Subject) + (1|Item)

Neither model A ($\chi^2(1)=0$, p=1) nor model B ($\chi^2(8)=14.855$, p=0.062) were better than the original winning model. The rated Semantic Similarity between critical reply and context question was therefore not affected by exposure to the stimuli.

Certainty (CER-R)

(W) CER-R ~ In/Directness * Polarity + (1|Subject) + (1|Item)
(A) CER -R ~ In/Directness * Polarity + exposure + (1|Subject) + (1|Item)
(B) CER -R ~ In/Directness * Polarity * exposure + (1|Subject) + (1|Item)

The model A was not better than the original winning model ($\chi^2(1)=0$, p=1). However, the model B explained the data significantly better than the winning model ($\chi^2(4)=183.25$, $p<0.001$) indicating that exposure to the stimuli did affect the Certainty ratings in a three-way interaction with the factors In/Directness and Polarity (Table C.9). A closer examination of the data indicates that direct replies did not seem to be affected by the degree of exposure in a systematic way. However, indirect replies (both those conveying a “yes” and a “no”) were interpreted with more certainty the more the subjects were exposed to them.

Table C.9: Summary of the fixed effects of the best fitting model for the rating of certainty (CER-R). Default treatment contrasts were used, such that the base level for Directness and Polarity were direct and no respectively. Exposure was coded as a continuous predictor.

FIXED EFFECTS (Certainty)			
Effect	β	SEM	t-value
Intercept (direct, no)	3.599	0.204	17.605
In/Directness (indirect)	-1.032	0.066	-15.542
Polarity (yes)	-0.069	0.081	-0.849
Exposure	0.001	0.052	0.027
In/Directness (indirect) : Polarity (yes)	-0.343	0.094	-3.656
In/Directness (indirect) : Exposure	0.157	0.017	9.175
Polarity (yes) : Exposure	0.010	0.017	0.563
In/Directness (indirect) : Polarity (yes) : Exposure	0.029	0.024	1.203

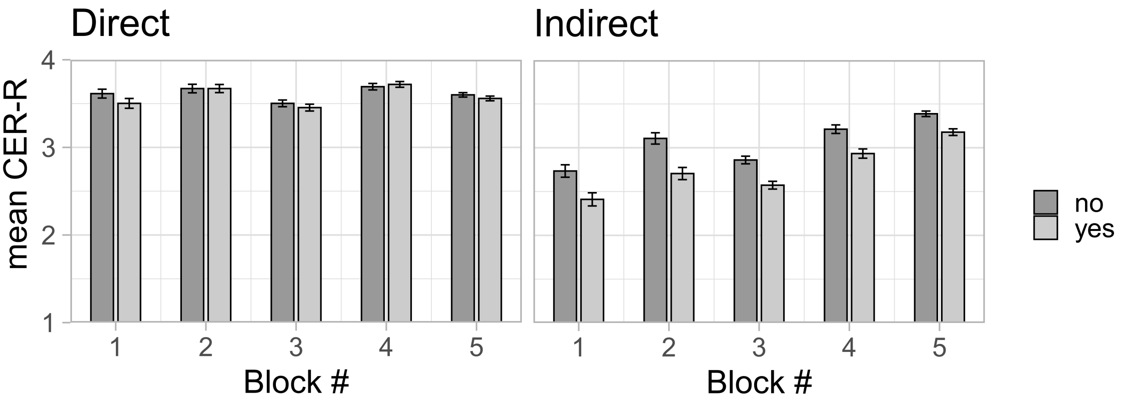


Figure C.2: Average Certainty ratings as a function of In/Directness, Polarity and Exposure.

C.5 Correlation between average scores by items and logRTs

A Person correlation was computed between all ratings averaged by items and the corresponding log normalized reaction times. All ratings correlated negatively and significantly with their logRTs after Bonferroni correction for 5 comparisons (COH-R: $p_{Bonf} <0.001$; R=-0.351; PRE-R: $p_{Bonf} <0.001$; R=-0.357; SSI-R: $p_{Bonf} <0.001$; R=-0.223; CER-R: $p_{Bonf} <0.001$; R=-0.275). The only exception was the rating of Directness, which was however still marginally significant after correction for multiple comparisons (DIR-R: $p_{Bonf}=0.068$; R=-0.149). Note that these correlations, while all modest in their size, are still remarkable considering that subjects were only given the instruction to be accurate, but were not instructed to be fast and were free to provide their ratings at their own self-chosen pace.

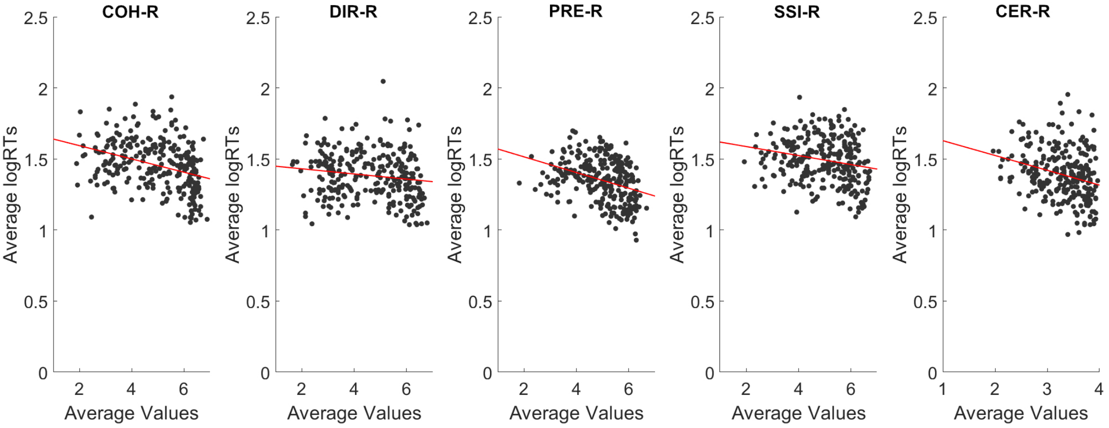


Figure C.3: Linear correlations between the average scores achieved by each items and the corresponding average reaction times for Directness (DIR-R), Coherence with the question (COH-R), Predictability (PRE-R), Semantic Similarity to the Question (SSI-R) and Certainty of Function (CER-R). Every observation corresponds to one item.

C.6 Visualization of the In/Directness effect by subject

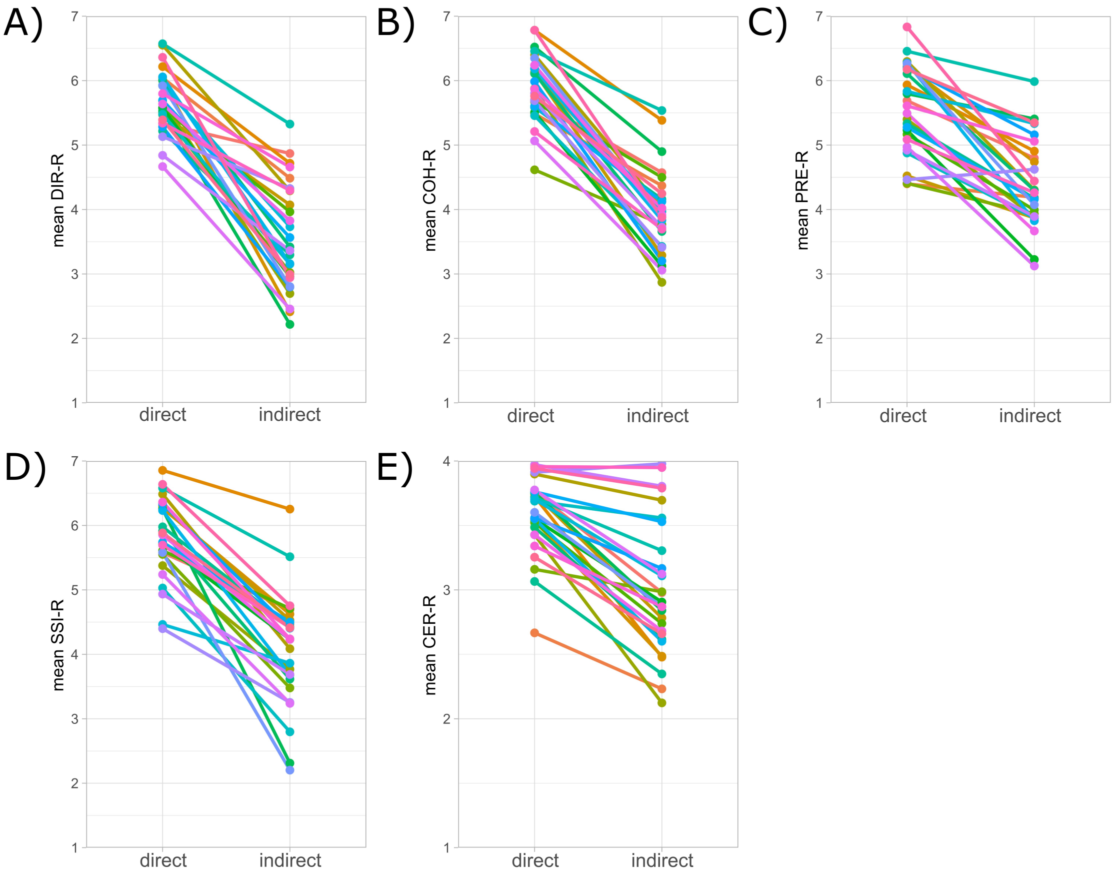


Figure C.4: Average ratings for the various dimensions as a function of Directness (direct, indirect) and displayed individually by subject (color): (A) Directness (DIR-R), (B) Coherence with the question (COH-R), (C) Predictability (PRE-R), (D) Semantic Similarity to the Question (SSI-R), (E) Certainty of Function (CER-R).

Eigenständigkeitserklärung zur Dissertation

Isabella Paola Boux

Erklärung zur Dissertation mit dem Titel "Communication beyond Form: How the Brain Processes Communicative Intention"

1. Hiermit versichere ich,
   - dass ich die von mir vorgelegte Arbeit **selbständig** abgefasst habe, und
   - dass ich **keine weiteren Hilfsmittel** verwendet habe als diejenigen, die im Vorfeld explizit zugelassen und von mir angegeben wurden, und
   - dass ich die Stellen der Arbeit, die dem Wortlaut oder dem Sinn nach anderen Werken (dazu zählen auch Internetquellen) entnommen sind, unter Angabe der Quelle kenntlich gemacht wurden, und
   - dass die Arbeit nicht schon einmal in einem früheren Promotionsverfahren angenommen oder abgelehnt wurde.
2. Mir ist bewusst,
   - dass Verstöße gegen die Grundsätze der Selbstständigkeit als Täuschung betrachtet und entsprechend der Promotionsordnung geahndet werden.

Isabella Paola Boux
Berlin, den 10.05.2023