fEMG as a window into conversational commitments[1, 2]

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Abstract

This paper presents a first experiment within a larger series of experiments on commitments taken on by our speech acts. The experiment serves as a proof of method, demonstrating that the physiological measure of facial electromyography (fEMG)—the recording of facial muscle activity—is a useful methodology for studying commitments in communication. Specifically, we experimentally demonstrate that we can use fEMG to measure norm violations in conversation and from there infer the commitments taken on by conversational participants. We explain how this methodology can be expected to contribute to a better understanding of what happens when we communicate.

Keywords: speech acts, commitments, physiological measures, facial electromyography.

1. Introduction

This study investigates whether facial electromyography (fEMG), the physiological methodology of recording facial muscle activity, can be a useful tool for exploring the assignment of commitments in conversation.

We start from the idea, found throughout the pragmatic literature, that by performing certain speech acts we take on commitments (e.g., Searle, 1976; Krifka, 2015; Geurts, 2019). Commitment in general is a normative notion: a commitment is an obligation to others to act in certain ways. For commitments arising from speech acts this entails that interlocutors may expect the speaker to act in accordance with the norms of their speech act. A fundamental and relatively uncontroversial case is that of assertions; with an assertion, the speaker takes on a commitment to the truth of the propositional content of their assertion. This specific commitment entails that the speaker will be interpreted as violating a norm of assertion if they continue by asserting something that is inconsistent with the earlier assertion. In this paper we will refer to such norms in general as 'norms of speech acts' or 'speech act norms' and to the commitments governed by these norms, undertaken by performers of the speech acts, as 'commitments from speech acts'.[3]

Recently, it has been argued that not just assertions but much of what happens in communication can be understood in terms of commitment undertaking (e.g., Geurts, 2019). While this is a

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[2]For all materials related to this study including item lists, experimental protocol, and full data output, see OSF repository: osf.io/j7rhc

[3]The 'norms of speech acts' referred to here should be distinguished from the 'norms *for* assertion' as used in the philosophical tradition which studies norms of assertability, i.e., the conditions under which it is epistemically permissible to make an assertion (Pagin and Marsili, 2021). The commitment approach that we work with here is not about assertability, but about the normative *effects* of making assertions (see also MacFarlane, 2011 for the difference).

very promising idea, a number of fundamental questions have as of yet remained open. They concern the role of the addressee in commitment uptake, commitment to different layers of meaning (Grice's 1975 'what is said' vs. implicatures, Potts' 2005 at-issue vs. not-at-issue content) and the idea of commitment lowering, for example by the use of evidential markers, such as parenthetical 'I hear'. In order to make headway in answering these questions, we first need to develop a methodology to gather reliable data on the assignment of commitments in discourse. Because of the difficulties that arise when one tries to elicit explicit judgments on commitments in the form of questionnaires, we developed a methodology that uses an implicit measure. This paper presents the proof of method.

Inspiration for the specific methodology developed comes from social psychology. Norms of speech acts are just one kind of social norms. Other western social norms are, for example, that we shake hands when we meet someone for the first time or that we keep some distance from people with whom we are not yet well acquainted. Bartholow et al. (2001) have investigated such broader social norms with the use of fEMG, the recording of facial muscle activity. They found a clear correlation between reading a short text in which a social norm was violated (e.g. someone refusing to shake hands) and activation of the *corrugator supercilii*, the muscle which spans the brow ridge and contracts when frowning, pulling the inner-eyebrow downward and medially. This is colloquially referred to as the 'frowning muscle.' This observation shows that the corrugator becomes active in the case of moral indignation, as a reaction to a social norm violation. If we take the normative nature of commitments from speech acts seriously, what happens if someone acts against the commitments from an earlier speech act is also a social norm violation, just as a refusal to shake hands. Therefore, we hypothesized that here too we would find a correlation between corrugator activity and the observation of a norm violation, in this case the observation of a conversational participant violating speech act norms by acting against their earlier commitment.

In the proof of method study presented here we test this hypothesis. We work with the relatively straightforward case of the commitments of a speaker who makes an assertion and we assume that speakers indeed commit to the propositional content of their assertions. We measure the corrugator activity of participants in the experiment while they are reading descriptions of short dialogues where a speaker says something that is either in accordance with or contradictory with what they committed to previously. We test the hypothesis that the corrugator activity increases in the latter condition compared to the former. If this hypothesis is confirmed, we can take this as evidence that fEMG can be used to measure norm violations in communication. So, the reasoning is as follows: once we have validated the methodology on the basis of this rather uncontroversial case, we can apply it to the open issues in later experiments and thus move forward our understanding of communication by obtaining an insight in the assignment of commitments during discourse.

The paper is structured as follows: in Section 2 we provide the theoretical and methodological background to this study. Section 3 explains the experimental design. Section 4 gives the results. We observed that there is indeed a correlation between violations of norms of speech acts (here a speaker contradicting themselves) and corrugator activity. In Section 5 we discuss the implications of our study. We argue that fEMG can indeed be used to measure norm violations in communication and thus, indirectly, also the commitments taken on (as they can be derived from the observed norm violations). This means that the methodology has the potential for

answering open questions in pragmatics. We conclude by discussing some limitations of the study.

2. Background

2.1. Theoretical Background

By performing certain speech acts we take on commitments. This is perhaps most obvious in the case of promises; when we utter a promise, we commit ourselves to taking an action in the future (e.g., Searle, 1976). For example, in uttering (1), the speaker becomes committed to undertaking the act of washing the dishes themselves, and addressees are now entitled to count on the speaker doing this:

(1) I'll do the dishes tonight. [PROMISE]

Commitment has also been argued to be the central notion to understand the speech act of assertion (e.g., Hamblin, 1971; Searle, 1976; Brandom, 1983; Geurts, 2019; Krifka, 2015, 2024). In asserting (2), the speaker becomes committed to the truth of the proposition expressed:

(2) Tom is a vegetarian. [ASSERTION]

The range of speech acts that are analysed in terms of commitments is still extending (e.g., Lauer, 2013 for directives, Krifka, 2015 for interrogatives) and recently it has even been argued that communication in general is first and foremost a matter of negotiating commitments, rather than, e.g., of conveying beliefs and intentions (Geurts, 2019).

What sets commitments apart from beliefs is that commitment is both a normative and a social notion; commitments are obligations to others to act in certain ways. Commissive speech acts such as promises commit the speaker to a future course of action; if we promise to do the dishes tonight, the interlocutors are entitled to rely on this being the case. With assertions, on which we focus here, the speaker gives a guarantee for the truth. This means that the addressee can expect us to act (linguistically and otherwise) in accordance with it. In the case of (2), for example, we should not continue by making a contradictory claim, like 'he eats a lot of meat.' So the commitment undertaken constrains how we should behave given what we have said. Of course, it is perfectly possible to act against our commitments in practice; we could choose to disregard our promise (1) and go for a run instead, likewise we could choose to assert both (2) and 'he eats a lot of meat' in full knowledge that they are incompatible utterances. Our commitments do not necessarily limit our actions, but they do constrain how we *should* act, and thus how others are entitled to expect us to act. Defying such commitments flaunts cooperative principles and puts the speaker at risk of social penalties, such as exclusion. All of this does not hold for beliefs. Beliefs are primarily private and our beliefs do not entitle other people to count on us doing certain things, or lead to norm violations if we don't act in accordance.

While the case of commitments made by the speaker through their promises or assertions is relatively uncontroversial in the literature, many other aspects of conversational commitments remain unclear. One concerns the role of the addressee. There is no consensus as of yet as to whether some action on the part of the addressee is needed before a commitment becomes accepted by the addressee as well (and thus enters the common ground as a shared commitment). Stalnaker (1978: 323) proposed that the essential effect of an assertion "provided that there are no objections from the other participants in the conversation" is that the proposition asserted is added to the common ground. Others have emphasized the proposal nature of assertion.

According to this idea, the proposition asserted does not get added to the common ground automatically; a speaker can only *propose* to add it to the common ground, and explicit actions by the addressee are required to actually *ground* it (e.g., Clark and Schaefer, 1989; Clark, 1996; Farkas and Bruce, 2010). Evidence for this could potentially be seen in the finding in psychological research that in conversations, even in what are seemingly monologues, there is continuous 'hmm-mm'-ing on the side of the hearer (Clark, 1996; Bavelas et al., 2000).

While the proposal nature of assertions has become more or less accepted nowadays, it has also become very popular to still treat the contribution of *certain* linguistic expressions, that is to say not-at-issue meaning components, as automatic updates of the common ground. Not-at-issue content is argued to be introduced e.g., by appositives (Potts, 2005), evidentials (Murray, 2017), and expressives (McCready, 2010). Opponents of this view have objected, however, that acceptance, let alone mutual commitment to content, always requires explicit moves by the interlocutor (Hunter and Asher, 2016), even in the constructions that are said to introduce not-at-issue content.

A second open issue in the literature concerns the relation between commitment and evidentials. Evidentiality markers, expressing the source of information we have for a claim, or more broadly, the grounds we have for a speech act, are often said to modulate the speaker's commitment (e.g., Murray, 2014, 2017). To illustrate this with an example, Murray claims that (3a), with the hearsay expression 'I hear', reduces the speaker's commitment to the proposition that Floyd won compared to (3b):

(3) a. Floyd won the race, I hear. (Murray, 2014: 5)
b. Floyd won the race.

This reduction in commitment can be analyzed in different ways. One way entails that commitment itself is a gradable rather than a black or white notion. In the literature, however, we also find opposition to such a gradable notion of commitment (e.g., Katriel and Dascal, 1989; Cornillie, 2017).

In addition to evidentiality markers, there is exploration on the impact of multiple factors that we might take together under the label of the 'directness' of expression on a speaker's degree of commitment as a whole (e.g., Moeschler, 2013; Mazzarella et al., 2018; Weissman, 2022; Bonalumi et al., 2023). The directness with which a proposition is communicated depends on whether it is asserted or implicated and whether the utterance is ambiguous. Mazzarella et al. (2018) showed that speakers are judged to be more blameworthy if they directly say content which is later found to be mistaken, in comparison to a speaker who has merely implicated the same proposition; directly-said content was considered to undertake a higher degree of speaker commitment and thus risks greater social penalties such as blame or future mistrust. Similarly, in digital communication, emojis with high meaning-agreement (i.e., less ambiguity) are interpreted as expressing a greater degree of commitment than those with lower meaning-agreement (Weissman, 2022). Whether an utterance is plausibly deniable or not has been used as a measure of commitment in multiple studies (e.g., Weissman, 2022; Bonalumi et al., 2023). The more direct a speaker's initial utterance, the less deniability the utterance affords them, and the more accountable the speaker is perceived to be. This suggests that directness signals higher speaker commitment. Thus the idea that commitment is a gradable concept, with directness serving as a key modulating factor, is an increasingly prominent hypothesis.

In order to meaningfully contribute to these and related open issues, it would be helpful to find a way to gather reliable data on the assignment of commitments in conversation. Only then will we know what a theoretical analysis should in fact account for and only then can we begin to discuss whether existing analyses are on the right track.

2.2. Methodological background

Over the last decade, several experimental studies have been conducted to learn more about conversational commitments. So far, these studies have worked with explicit judgments of commitment using questionnaires. There are however difficulties with this methodology.

One concerns the specific question which participants are asked to answer. De Marneffe et al. (2019), for example, operationalize the notion of commitment in terms of certainty; they ask participants how certain the speaker is that a specific piece of content is true. As we have seen, however, commitment is crucially not the same thing as belief (see also Bary, 2025 for the need to distinguish the two). Commitment has an important normative dimension, which is not captured in this operationalization.

Weissman (2022) asks participants two questions: one in terms of commitment directly ("Have I committed to saying X?") and one in terms of deniability ("Could I convincingly deny that I said X?"). Both have their disadvantages, however. A problem with the former is that the term 'commitment' has multiple usages in daily life. In addition to the social and normative use that this paper is concerned with, we can say, for example, that Roger is committed to birdwatching and spends considerable amounts of time and money pursuing this hobby, or that after some thinking Frank has decided to go to the cinema and is now committed to this plan. These examples, from Michael (2022: 2), show that the term 'commitment' in daily life is not always normative nor social. That means that one can never be entirely sure which interpretation participants apply in the task. The problem with the latter question is that 'convincingly' introduces beliefs again. And, even worse, in our post-truth era it seems not impossible to convince people of a denial of what just happened.

A more general complication with explicit questions lies in the fact that self-modulation may impact accurate data collection. Self-modulation occurs when participants themselves, whether intentionally or not, censor their actual immediate response to a given question. This often stems from social desirability bias, where a participant's personal motivation to please (or, in rare cases, rebel against) researchers and future audiences of their data, may influence the answers they provide (Crowne and Marlowe, 1960; Dodou and de Winter, 2014). The data collected may not be a true reflection of a participant's initial intuitive response. What is more, apart from very straightforward cases, the phenomenon of commitment assignment seems too subtle to try to measure using explicit judgments. For all of the above reasons, we felt that it was necessary to develop a methodology to trace commitments in conversation that works with an implicit measure, in particular with one that is very sensitive, immediate, and involuntary, and thus difficult to self-modulate.

The methodology we developed makes use of facial electromyography, or fEMG. This is a physiological methodology in which surface electrodes measure muscle unit action potentials (μV) reflecting the activation of specific facial muscles. The degree of activation of various muscles can be mapped onto the emotional states of the participants, providing information

about the valence of their response. We can infer at least the elementary emotions—sadness, happiness, fear, anger, surprise, and disgust (Ekman et al., 1972)—from the selective activation of specific muscles (van Boxtel, 2010). The *corrugator supercilii* (the 'frowning muscle' with a lower eyebrow angle) is known to become activated in a person's negatively-valenced state or reaction, including in situations which trigger the elementary emotions of fear, sadness and anger.

Inspiration to apply this methodology to our topic comes from social psychology. Bartholow et al. (2001) have shown that the activation of the corrugator muscle extends to more complex negative affective states such as moral indignation. They found a clear correlation between reading a short text containing a social norm violation (e.g., someone refusing to shake hands) and activation of the corrugator muscle. Since commitment, too, is a social and normative notion, and acting against those commitments is generally understood as a form of social norm violation, we hypothesized that we would also find a correlation between corrugator activity and the observation of a speaker violating their discourse commitments. This parallel between norms of speech acts and other social norms has been the primary motivation for choosing the methodology of fEMG.

The activation of our facial muscles meets the requirements we have for our measure: it is very sensitive, immediate and involuntary, and thus difficult to suppress (Fridlund and Cacioppo, 1986; Rutkowska et al., 2024). fEMG is thought to provide more precise and nuanced data than video-based facial coding, a methodology in which a participant's face is recorded and affective response judgments are based on appearance alone, determined by individual researchers or using AI methods. In an advantage over this methodology, fEMG is able to detect and record minimal changes in facial muscle activity which do not trigger significant muscle contraction, collecting data prior to (or entirely without) any visible activity in the face (van Boxtel, 2010; Rutkowska et al., 2024). What is more, with proper application, fEMG provides highly sensitive measurements with excellent temporal resolution (100–200ms post-stimulus), making it particularly valuable for performing various types of analyses, such as time-course analysis (e.g., van Boxtel, 2010; 't Hart et al., 2018).

If we take a broader perspective, we also see advantages of fEMG over other widely-used implicit measuring techniques. Event-related potentials recorded from EEG measurement appear to respond more slowly than fEMG within the same task (Bartholow et al., 2001). Furthermore, eye-tracking or EEG data directly record visual attention and cognitive effort, compared to the highly localized and preconscious primary source of facial muscle movement (Cacioppo et al., 2000). Thus those methods may be comparatively weaker at providing direct insight into the affective responses which interest us, which is offered by fEMG. A further advantage is the fEMG experimental set-up, which is not invasive and in certain cases may be less restrictive or uncomfortable for the participant than wearing an EEG cap or using an eye-tracking headset or headrest (Bell et al., 2018). This may in turn result in more naturalistic data. Finally, an experimental session is relatively cheap. Once one is in possession of the equipment, the only costs are for electrodes, gel, and cotton pads.

As a result, fEMG, as an implicit measure, offers advantages over both explicit self-report methods of commitment assignment and other physiological measures, by providing more precise, real-time tracking of dynamic activity of specific facial muscles, such as the corrugator,

which has been shown to be linked to negatively-valenced states, of which indignation is one. Therefore, we investigated its use in learning more about commitments from speech acts.

3. Experimental design

3.1. General set-up

In this section we will present the design of the experiment conducted as a proof of method study to find out if fEMG can indeed be a useful tool in investigating conversational commitments. The experiment was set up as follows: participants read short descriptions of social interactions between two people. While reading, their corrugator activity was continuously recorded, with activity during the critical segment to be compared with baseline muscle activation. From this we may derive a participant's implicit judgment of the given items.

The descriptions were of two main types, shown in Table 1: speech act items and more general social interaction items of the kind used in the experiment of Bartholow et al. (2001) (from now on 'social items' for short, with the caveat that the speech act items are obviously social in nature too). While we are ultimately interested in the speech act items, by including the social items we were able to ensure that our experimental setup was sufficiently sensitive to detect effects of social norm violations. The second reason to include the replication is to facilitate a qualitative comparison between the two kinds of items. While the differences between the two are not minimal enough for a true, quantitative comparison, we think it will still be interesting to observe, for example, whether the development of the corrugator activity over time follows a similar trajectory.

As in Bartholow et al.'s experiment, our social items have the manipulation of being either norm-conforming (shaking someone's hand) or norm-violating (refusing to shake someone's hand). Full example items for all conditions of the experiment can be found in Table 1. The hypothesis for the social items was that we will confirm the results from Bartholow et al., in other words, that we will indeed find increased corrugator activity for the norm-violating compared to the norm-conforming conditions.

Within the speech act items, the core of the experiment, our main focus is on assertions. As mentioned in earlier sections, the speech act of assertion is seen as a fundamental and relatively uncontroversial way to take on commitments in communication; someone who makes an assertion takes on a commitment to the truth of the proposition they express. This commitment entails that the speaker will be taken to be violating a norm if they continue by asserting something that is inconsistent with the earlier assertion. Thus, here too, we work with a norm-conforming condition (follow-up speech act congruent with earlier assertion) and a norm-violating condition (follow-up speech act incongruent with earlier assertion). Our hypothesis was that also in this case the corrugator activity is higher in the latter condition compared to the former.

As can be seen from Table 1, we also include speech act items phrased as a question rather than assertion. These items function as a check to ensure that the speech act of assertion indeed plays a role in the activation of the corrugator in the assertive items. If we worked only with assertive items and we found higher corrugator activation in the incongruent condition compared to the congruent one, this could in principle also be due to a clash at the word level, between the words 'vegetarian' and 'meat' in the example used in the table, or just at a propositional level, rather than (also) at the commitment level. By adding speech act items that have the same

SPEECH ACT ITEMS		
		Joyce and Niels are discussing the eating habits of their friend Tom.
Assertion	Congruent	Joyce says: "Tom is vegetarian. He eats a lot of tofu."
	Incongruent	Joyce says: "Tom is vegetarian. He eats a lot of meat."
Question	Congruent	Joyce says: "Is Tom a vegetarian? He eats a lot of tofu."
	Incongruent	Joyce says: "Is Tom a vegetarian? He eats a lot of meat."
SOCIAL ITEMS		
		Jonathan and Natasha are meeting their new female manager.
	Norm-Conforming	Jonathan shakes the woman's hand.
	Norm-Violating	Jonathan refuses to shake the woman's hand.

Table 1: (Translated) example items for all conditions.

vocabulary and propositional content as the assertive ones but report a different speech act, we are better informed as to whether the speech act plays a role. Questions were chosen because they do not commit the speaker to the truth of the propositional content (e.g., Gunlogson, 2008). When we ask 'Is Tom a vegetarian?' we clearly do not commit to Tom being a vegetarian. Our hypothesis for this control part of the experiment is that the speech act does play a role, and thus that the difference in corrugator activity between congruent and incongruent assertive items is significantly greater than the difference in activity between congruent and incongruent question items. Note that we expect that question items may lead to corrugator activity too. This is because questions are also associated with certain speech act norms, such as not asking questions to which one already knows the answer. Hence, the question items may also involve the violation of a speech act norm, though intuitively a less egregious one. A note on the labeling of the conditions: the terms 'congruent' and 'incongruent' are based on the assertive items. For ease of reference, we use the same terms for these conditions in their question version, even though they do not retain meaning.

After the fEMG part of the experiment, participants were also asked to complete a questionnaire, rating the 'acceptability' of the speaker's congruent or incongruent utterance. The purpose of including a questionnaire in this experiment was simply to gather an additional layer of explicit judgments for qualitative comparison with the fEMG data, enabling observation of any correlations. While a number of the disadvantages of questionnaires mentioned in Section 2.2, such as being susceptible to self-modulation, obviously still hold, we believed that questionnaire data could still provide some insight in our specific case. This is because we work with a very clear case (the reliability of questionnaire data may diminish in subtler cases) and we intentionally use a normative formulation of the question asked to participants (in terms of 'acceptability') to capture the notion of commitment. And most importantly, in the set-up of our experiment, the explicit judgments are just an additional check to establish that fEMG can be used to trace conversational commitment, on top of the internal comparison of the fEMG data for the various conditions, which provides the main evidence. Furthermore, as this study is an initial exploratory proof of method, should the fEMG portion produce a null result, it would have remained interesting nonetheless to refer to what the explicit judgments had been.

3.2. Materials

Both social items and speech act items began with a brief contextualizing sentence, describing an interaction between two people. In all cases, the critical manipulation occurs in the final 5000ms follow-up segment presented to the participant. All items were presented in Dutch; translated example items in all conditions are presented in Table 1.

3.2.1. Social norm items

Figure 1 depicts the on-screen presentation of a single social item trial. Thirty-two written social item sets were adapted from Bartholow et al. (2001) and Hubers et al. (2016). These items consisted of a distractor image, a brief story introduction and then a follow-up action, with a critical manipulation of the norm-conformity of the follow-up action; either norm-conforming or norm-violating. The story introduction segment had a duration on-screen of 4000ms, with the critical follow-up segment lasting 5000ms. The distractor image shown per-trial serves to provide a neutral pause in which the corrugator may relax, from which we can calculate the baseline muscle activity.

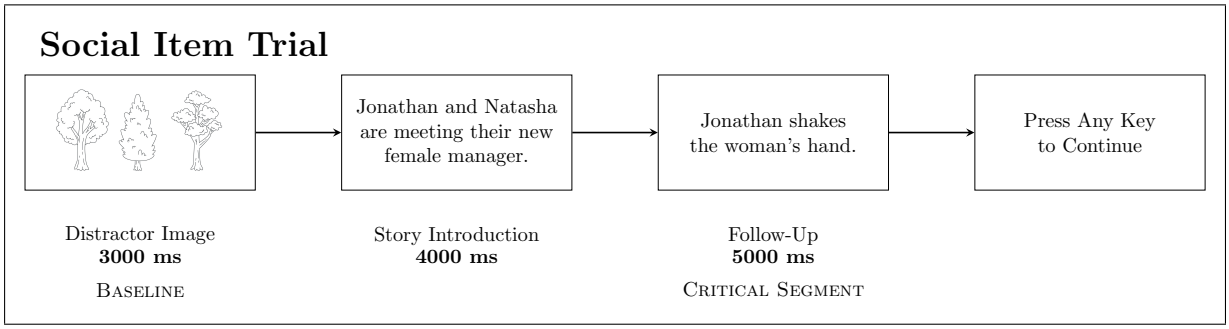

Figure 1: A flowchart showing the on-screen presentation of a single social item trial (norm-conforming). The distractor image here is for illustrative purposes only. The segments relevant for analysis are marked as Baseline and Critical Segment.

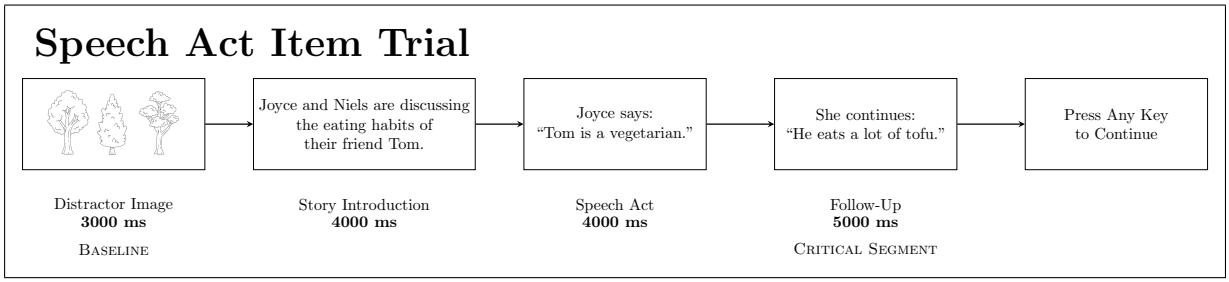

Figure 2: A flowchart showing the on-screen presentation of a single speech act item trial (assertion, congruent). The distractor image here is for illustrative purposes only. The segments relevant for analysis are marked as Baseline and Critical Segment.

3.2.2. Speech act items

Figure 2 depicts the on-screen presentation of a single speech act item trial. Sixty-four written item sets were designed (sixteen of each condition: assertion and question items, with congruent

and incongruent follow-ups). As established, assertions are the focus of our fEMG exploration. The assertion items constituted of a distractor image, a brief story introduction, a speaker's initial assertion, and then a follow-up assertion, with a critical manipulation of the congruence of the follow-up assertion. With respect to the speaker's initial assertion, their follow-up was either congruent or incongruent (in a similar way to the norm-conformity of the social items). The speech act items were presented on-screen as a 4000ms story introduction segment, a 4000ms speech act segment, and the critical follow-up segment again lasting 5000ms.

As previously highlighted, to ensure that the speech act of assertion indeed plays a role in activation of the corrugator, we also included question speech act items. These items use the same content as their assertion counterparts, but the speech act segment is formulated as a polar interrogative (the standard form of yes/no questions). Otherwise, the question items had an identical structure to the assertion items, and the critical follow-up segment remains unchanged. By preserving the content of the assertion items, this ensures that any difference in the levels of corrugator activity between the assertion and question items are, in fact, related to the speech act type.

As fEMG recording readily detects emotional reactions to items, the content of all speech act items was designed under limitations. If an item were to contain strongly valenced content, corrugator activation can be observed as a simulation effect (that is, in the participant replicating a negative facial expression in response to reading negative content, such as someone feeling furious), rather than in moral evaluation of the content ('t Hart et al., 2018), which we hope to elicit here. To avoid any simulation effect, all speech act items used non-emotive language and did not describe any other social norm violations. It was emphasized that it was the same person uttering both the initial speech act and the follow-up, to confirm to the participant of the experiment that it is indeed the speaker who is following-up their own utterance either congruently or incongruently. Furthermore, traditionally-gendered Dutch names were used so that referential pronouns could be used clearly within the items when necessary.

3.2.3. Pretesting

A pretest of the speech act items was conducted in order to ensure that participants perceived the speaker's utterances to be congruent in the congruent condition, and incongruent in the incongruent condition.

Forty participants (over 18 years old, native Dutch speakers with no known learning or reading disorders) were recruited through the Radboud University SONA systems. The study was conducted with ethics approval from the Radboud Ethics Assessment Committee for Humanities, and informed consent was obtained from all participants prior to the study. Participants saw seventy-five pseudo-randomized speech act vignettes of the structure shown in Table 1. For each story introduction, participants saw both a congruent and incongruent follow-up version. Participants were asked to indicate to what extent the speaker contradicted themselves on a 5-point Likert scale, ranging from 1 ('completely contradictory') to 5 ('completely not contradictory'). Here, only the assertion items were pretested (thus not the question items) as these were the items for which we had specific hypotheses, i.e., that participants would rate the congruent and incongruent continuations as not contradictory and contradictory, respectively. For an item set to qualify for the main experiment, the mean rating for the incongruent version had to

be below 2, and the mean rating for the congruent version above 4. Taking self-contradiction as an indication of incongruence, this criterion ensures that the incongruent and congruent versions were indeed perceived as such. Sixty-seven item sets met the criteria, out of which sixty-four were selected, to allow for sixteen trials per condition in the main experiment.

3.3. Participants

In the main experiment sixty-two participants (47 female, 15 male, age range: 18–63, mean age: 24) were recruited via the Radboud University SONA systems, and compensated with retail vouchers or academic credit. All participants were adult native speakers of Dutch, with no known reading or learning disorders, and with normal or corrected-to-normal vision. No participant in the fEMG study had participated in the pretest. Participants with a history of Botox injections were excluded from participation, as these can inhibit the motor action of muscles targeted in fEMG. Again, the study was conducted with ethics approval from the Radboud Ethics Assessment Committee for Humanities, and informed consent was obtained from all participants prior to the study.

3.4. Procedure

The experiment took place in the Center for Language Studies Laboratory at Radboud University (Nijmegen). The fEMG signal was recorded using Biopac hardware (MP150 module and EMG100C Electromyogram Amplifier) and Biopac's Acqknowledge software (BIOPAC Systems, 2024). Three surface electrodes were attached to the participant; one acting as the ground (a location on the hairline with minimal palpable muscle activity), and two bipolar corrugator recording sites (above the eyebrow in line with the pupil and on the inside of the eyebrow). The electrode placement was based on conventions taken from the Facial Action Coding System (Ekman et al., 1972) and the seminal guidelines for EMG developed by Fridlund and Cacioppo (1986). The electrodes were referenced to the others automatically within the Acqknowledge software system. The electrode sites were cleaned with abrasive gel and alcohol to lower inter-electrode impedance. This electrical impedance (a measure of the opposition to electrical flow, in kΩ) was measured per participant prior to recording; when impedance is too high this can result in an unclean signal and the fEMG signal can be lost amongst noise.

The trials were presented to the participants using OpenSesame software (Mathôt et al., 2012). Two preparatory trials familiarized the participant with the procedure. Then each participant read ninety-six pseudo-randomized vignettes (sixteen per condition), presented line-by-line in time-locked segments. Each trial was preceded by a 3000ms distractor image, from which to calculate the baseline muscle activity relative to the critical follow-up segment of that trial. Rather than employing a fixation cross which is common in other methodologies, participants saw the same picture of a sunlit path through a forest; using an image such as this rather than a fixation cross is thought to elicit a more relaxed level of baseline muscle activity ('t Hart et al., 2018).

Although the on-screen presentation of each segment within a given trial was time-locked, advancement to the next trial was self-paced (in the format "Press any key to continue") so that participants themselves chose how quickly to proceed through the experiment. They were encouraged to take this opportunity for breaks whenever necessary, avoiding fatigue as far as possible. Participants were asked to read the items silently (as opposed to out loud) to control

for possible muscle interference. To ensure that the participants were sufficiently attending to the items, twelve true/false comprehension questions were randomly interspersed amongst the speech act items. These questions referred to the story introduction, so the same question was asked no matter the speech act type, or congruence of the follow-up. Participants were to be excluded if they made more than two errors on these comprehension questions.

Following the fEMG portion of the experiment, participants completed a questionnaire hosted via Qualtrics. In this questionnaire, they were presented again with the same sixty-four speech act items, including the question items. Participants rated the 'acceptability' of the speaker's congruent or incongruent follow-up on a 1–5 Likert scale.

4. Analysis

4.1. Data preparation

Files recorded with BIOPAC's AcqKnowledge software were imported into Matlab for pre-processing. Taking recommended preprocessing steps for fEMG (van Boxtel, 2010), the raw fEMG signal was filtered with a 20–500Hz band-pass filter and a 50Hz notch filter (to remove potential mains power supply electrical interference from the recorded signal). The signal was then rectified and the key segments (per-trial, the 3000ms fixation segment and 5000ms critical follow-up segment) were isolated and smoothed using the LOESS method. The mean absolute value of the 3000ms fixation segment was calculated per-trial, in order to obtain a baseline measure of corrugator activity. The 5000ms follow-up segments were divided into 50 100ms bins, an interval which provides optimal temporal resolution to track rapid dynamic facial muscle activity while largely avoiding random error (van Boxtel, 2010; van Boxtel and van der Graaff, 2024). The amplitude per bin was expressed as a percentage of the baseline mean absolute value for that trial. This method is proposed to account for both intra- and inter-participant variation in EMG amplitude (see van Boxtel and van der Graaff, 2024 for justification). These data were then exported from MATLAB to R for analysis.

One participant was excluded on the basis of failed comprehension questions, and a further three on the basis of data loss during recording. Upon evaluation of the impedance measured prior to recording, sixteen participants with high (greater than 40kΩ) impedance were excluded from the main analysis. This resulted in forty-two optimal impedance datasets for primary analysis (29 female, 13 male, age range: 18–63, mean age: 24). When these high-impedance participants were included in a later analysis, a pattern similar to those described below was observed.

4.2. Results

The mean proportions of baseline muscle activity (i.e., the corrugator activity expressed as a percentage of the baseline) across the conditions were analysed in R using linear mixed effects models, as implemented in the 'afex' package (Singmann et al., 2024).

4.2.1. Social norm items

For the social norm items we hypothesized to find that there would be more corrugator activity for norm-violating items compared to norm-conforming ones. To test this, we constructed a linear mixed effects regression model predicting mean corrugator activity based on congruence, including random intercepts for participants, which was the maximally converging model. A likelihood ratio test was used to evaluate the significance of the congruence effect. Figure 3

shows the by-participant mean values per condition, with Figure 4 showing this as a time-series plot over the critical segment. A likelihood ratio test indicated a significant main effect of congruency ($\chi^2(1) = 40.36$, $p < .001$). The results indicate increased muscle activity for social norm violations as opposed to norm conforming conditions (M_{diff} = 26.3, 95% confidence intervals: [18.2; 34.3]), confirming the results from Bartholow et al. (2001).

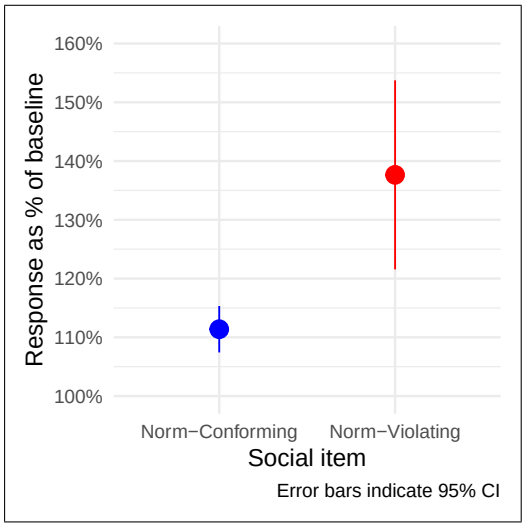

Figure 3: By-participant mean values of social conditions

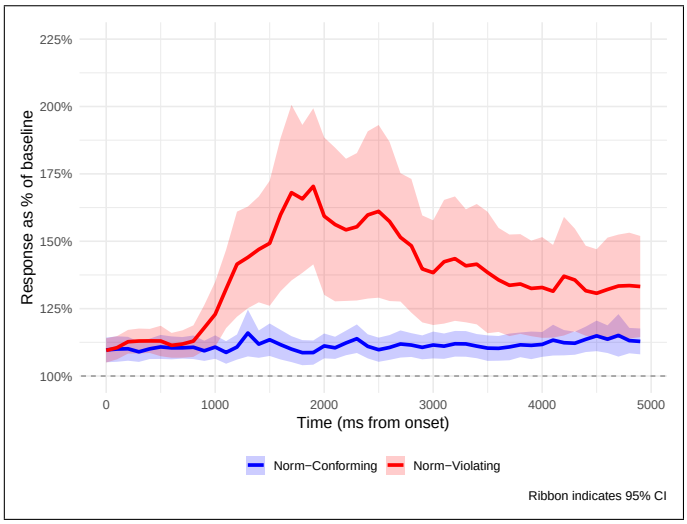

Figure 4: By-participant mean values of social conditions over critical period

4.2.2. Speech act items

For the speech act items, we hypothesized to find (i) that assertions would show higher corrugator activity for incongruent items compared to congruent ones, and (ii) that the difference in corrugator activity between congruent and incongruent conditions would be more pronounced for assertions than for questions. To test these hypotheses, we constructed a linear mixed effects regression model predicting mean corrugator activation based on congruence, speech act type, and their interaction. This model included random effects for both participants and items. Likelihood ratio tests revealed a significant main effect of congruence ($\chi^2(1) = 50.57$, $p < .001$) and a significant interaction between congruence and speech act type ($\chi^2(1) = 5.29$, $p = .021$), while the main effect of speech act type was not significant ($\chi^2(1) = 0.43$, $p = .514$).

These results support our hypotheses. Assertions showed greater corrugator activation for incongruent follow-ups compared to congruent ones (M_{diff} = 25.5, 95% CI: [17.68;33.22]), consistent with hypothesis (i). Moreover, this difference was significantly larger than the corresponding difference for questions (M_{diff} = 12.8, 95% CI: [5.74;20.03]), confirming hypothesis (ii). The significant interaction highlights that congruency effects differ by speech act type.

Figure 5 illustrates the by-participant mean corrugator activation for assertion conditions, clearly showing a larger difference in activity between congruent and incongruent items, with Figure 6 as a time-series plot over the critical segment. In contrast, Figure 7 and Figure 8 show a subtler pattern for questions, with smaller differences between conditions.

Judging from the graphs, the time plots for the social norm and assertion data exhibit a strikingly similar pattern, with comparable shapes and similar onset timings, suggesting a qualitative resemblance between the two datasets.

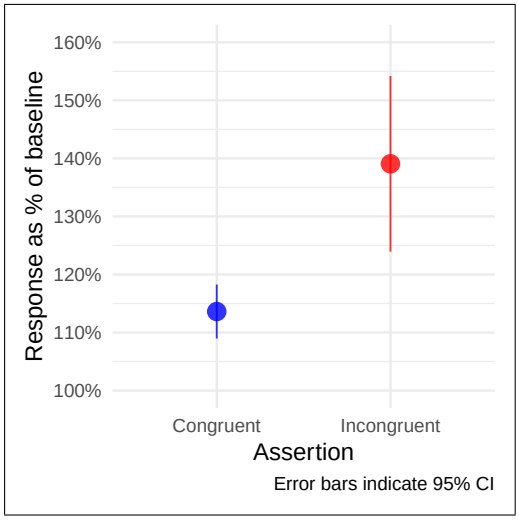

Figure 5: By-participant mean values of assertion conditions

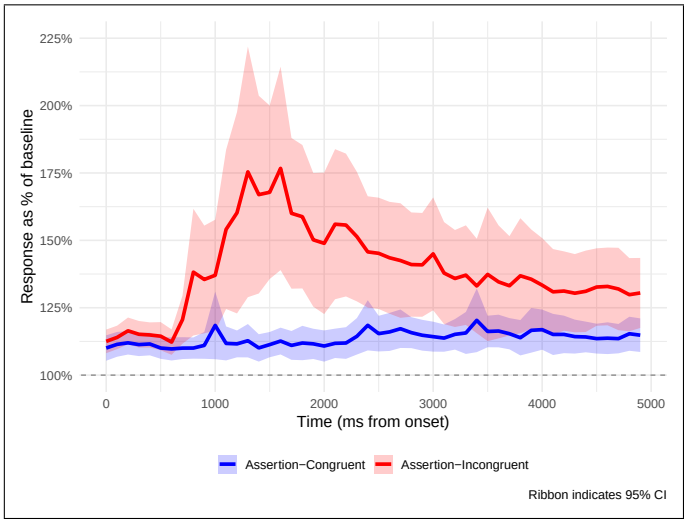

Figure 6: By-participant mean values of assertion conditions over critical period

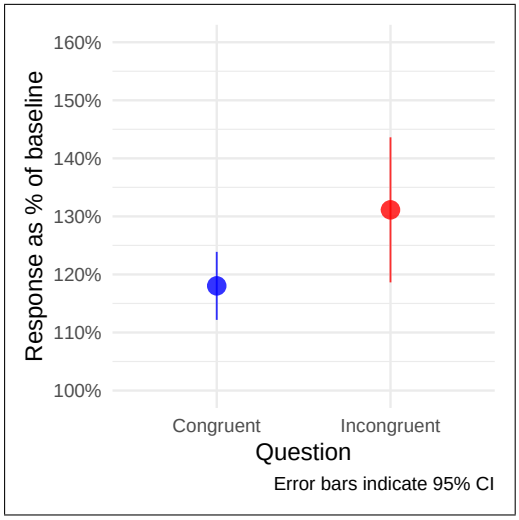

Figure 7: By-participant mean values of question conditions

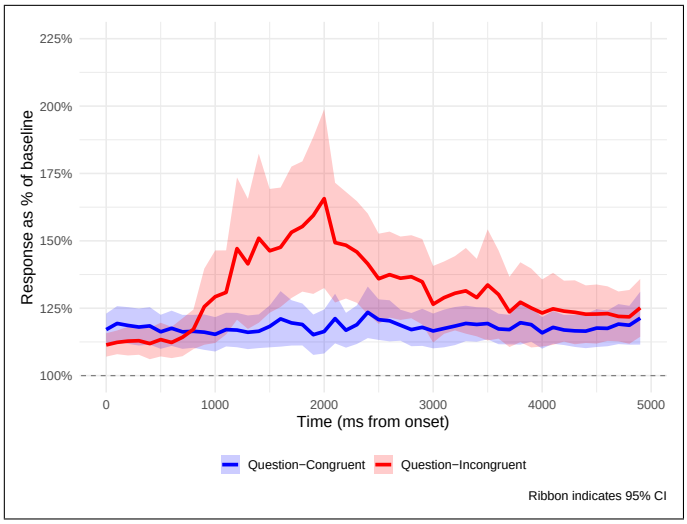

Figure 8: By-participant mean values of question conditions over critical period

4.2.3. Questionnaire data

For the questionnaire data, we hypothesized to find (i) that there would be a significant interaction between speech act (assertion vs. question) and congruency (congruent vs. incongruent), such that the effect of congruency would be larger for assertions than for questions, and (ii) that incongruent assertions would be judged significantly less acceptable than congruent assertions.

To test the first hypothesis, we constructed an ordinal mixed-effects model predicting acceptability ratings for both assertion and question items on the basis of speech act (assertion vs. question),

congruency, and their interaction, including random intercepts for participants and items. In line with the hypothesis, there was a significant interaction in the expected direction; the effect of congruency was significantly larger for assertions than for questions (mean differences of, respectively, 3.9 and 2.1; β = 2.6, SE = 0.1, Z = 18.5, $p < .001$).

To test the second hypothesis, we constructed an ordinal mixed-effects model predicting acceptability ratings for assertions (1 to 5, included as an ordinal variable) on the basis of congruency (congruent vs. incongruent), including random intercepts for participants and items. For this and the subsequent analysis, we relied on the 'clmm()' function from the 'ordinal' package (Christensen, 2022) in R. In line with the hypothesis, incongruent assertions were judged significantly lower than congruent assertions (β = -6.8, SE = 0.2, Z = -31.2, $p < .001$).

The results indicate that our hypotheses have indeed been confirmed. Incongruent assertions were judged significantly less acceptable than congruent assertions, and an interaction effect was observed, such that the effect of congruency is more pronounced for assertions than for questions. This appears to corroborate the interpretation of the fEMG findings, in which the effect of congruency is more pronounced for assertions than for questions. This again indicates a role of speech act type in a speaker's commitment.

5. General discussion

In this study we have shown that fEMG can be used to learn more about the commitments taken on in a conversation. We have started from the idea prevalent in the theoretical literature that certain speech acts come with norms and introduce commitments. Specifically, assertions commit us to the content expressed, which means among other things that we should not continue with a contradictory statement and that it would be a norm violation if we did. Inspired by the work by Bartholow et al. (2001) who found that the corrugator muscle becomes active when we perceive norm violations in social situations, we have extended this idea to the domain of speech acts.

Specifically, we have conducted a conceptual replication of Bartholow et al.'s experiment on violations of broader social norms and tested whether increased muscle activity is also found with the norm violation of acting against the commitments that we take on through our assertions. In both social items and speech act items our hypotheses were confirmed; we indeed recorded increased activity of the corrugator muscle in both cases of social norm violation and violations of norms of speech acts. In this way we have shown, on the basis of the rather straightforward case of the commitment of the speaker to the truth of the content of their assertions, that fEMG can be used to measure norm violations in communication, and indirectly also the commitments taken on by conversational participants, as they can be derived from the observed norm violations.

Now that we have established this methodology on the basis of a relatively straightforward case, it can be used in future studies to contribute to theoretically interesting open issues in this domain as discussed in the introduction. Advantages of fEMG over other methods are that the responses recorded are very sensitive, immediate, and involuntary, and it offers the option to look at time courses, an attractive feature we have not exploited in this study.

Our immediate follow-ups include an experiment on the commitments of the addressee (is some action on the side of the addressee required before something becomes a shared commitment?) and hearsay evidence (do such markers indeed reduce commitment as has often been claimed, see, e.g. Murray 2017). Further options include evidentiality more in general, the relation

between commitment and different layers of meaning (at-issue vs. not-at-issue, what is said vs. implicatures) and commitments *de lingua* (Harris 2016; Hess et al. 2023). For all these issues, fEMG now offers a window into conversational commitments.

It is important to also stress what this study is not. First, the experiment should not be taken to say much about questions. The questions have been included simply as a control condition to ensure that the speech act type of assertion indeed plays a role in the activation of the corrugator in the assertive items. As mentioned earlier, questions are understood to come with their own norms, e.g. in most contexts, we shouldn't ask questions to which we already know the answer and it may lead to indignation or confusion if we do. In creating the items, we have taken the assertions as our starting point, which results in question items which do not converge on a clear hypothesis. For some items, both the 'congruent' and the 'incongruent' condition (remember that the labels are based on the assertions) violate the norm of not asking questions to which we know the answer already (e.g., 'Is the library old? It was built in the sixteenth / twenty-first century') while for others only one of the conditions violates this norm (e.g., 'Is Tom a vegetarian? He eats a lot of tofu/meat'). This works for our purposes (a control to find out if the speech act performed plays a role), but the results should not be taken as telling us much about questions themselves, other than that the commitments are different from—or at least less pronounced than—the ones within assertions.

Second, the similarities between the speech act items and the social items are certainly suggestive, as is the correlation between the explicit judgments of acceptability, a normative notion, and the fEMG data. The emerging picture sits perfectly within a normative view on communication. Still, it would not be justified to take this experiment as proving a primarily normative view on communication. This is because the corrugator is also known to become active in the case of confusion (Durso et al., 2012). So, although the results fit a normative view very well, it is not excluded that they are in principle also compatible with a view where communication is primarily a matter of conveying beliefs and intentions, as in, for example, Bach and Harnish (1979).

In conclusion, this study demonstrated that the physiological method of fEMG offers a promising and reliable method for investigating the dynamics of commitment attribution during communication. Through effective detection of norm violations in conversation, fEMG allows inferences about the commitments undertaken by conversational participants. Thus this methodology has been established as a valuable tool for capturing nuanced aspects of communicative behavior, setting the stage for further exploration of how commitments are attributed, maintained, and negotiated.

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