Title of the paper

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Abstract

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Introduction

Among the most crucial distinctions between humans and other animals are the sophisticated means of communication humanity has developed. Language, at its best, allows humanity an unlimited scope of communication, providing the groundwork for stable social interactions as well as the efficient organization and exchange of information that builds the basis for cumulative scientific advancement. Nonetheless, our understanding of the architecture of our cognitive language system, the very thing that allows for the accumulation of knowledge and understanding is not only limited, but has also received surprisingly little attention in the respective fields of research.

Some of the earliest and perhaps also most influential contributions to the understanding of the human language apparatus were made by Carl Wernicke (1874) and Paul Broca (1861), who's discoveries both hinge upon the assumption of strong anatomical modularity of the (human) brain. Their respective infamy is both contingent upon the identification of areas in the brain thought to be responsible for the comprehension/production of language through the observation of the double-dissociation between cognitive functionality and cognitive trauma. While this strictly localist view of language processing in the brain has long since made way for the assumption of the interconnection of different areas and functions within cognitive science, the make-up of information processing within the brain remains a fruitful field of research to this day. One recent theory that accounts for (among others) the make-up of the human language system is the so-called *neural-reuse hypothesis* (Anderson, 2010). It's principle thought is that more complex neurological mechanisms (i.e. the language system) are comprised of the exaptation of (evolutionary) earlier, more basic mechanisms, often without abandoning their original functionalities. Importantly, this account is functional and not anatomical in nature and does not specify the makeup of any certain process.

An offshoot of this hypothesis that has repeatedly been shown in recent work is the reuse of inhibitory mechanisms in the processing of (sentential) negation. Several researchers postulate (and provide evidence for) a structural relationship between motor inhibition and the processing of sentential negation in that they share parts of their processing apparatus. This relationship manifests itself in the deleterious influence on participants performance in several tasks that is observed if both motor inhibition and sentential negation are being processed at the same time (see: Aravena et al., 2012; Beltrán et al., 2018, 2019; de Vega et al., 2016; García-Marco et al., 2019; Montalti et al., 2023). Despite the apparent replicability of this effect, why and how inhibition seems to be a prerequisite for the processing of negation is yet to be discovered.

Methodologically, the current study is built upon the work of both Beltrán et al. (2018) and Montalti et al. (2023). They both employ a Stop-Signal paradigm combined with the processing of sentential negation to provide evidence that cognitive inhibitory mechanisms are involved (being reused) in both motor inhibition and the processing of negation (by the processing of sentential negation). To do so, they both have participants read action sentences (made up of two words for Montalti et al. or whole sentences for Beltrán et al.) that are either affirmative or negated. Both report a deleterious influence of sentential negation on the efficacy of motor inhibition that manifests itself in a respectively longer *Stop Signal Reaction Time* (SSRT). How and why both processes seem to share resources however is a question neither study attempts to answer.

An account that might provide insights into the nature of shared resources between sentential negation and (motor) inhibition is the two-step hypothesis (Dudschig & Kaup, 2018; Kaup et al., 2006). Its fundamental premise is that in-order to process negation (i.e. *the door is not open*), two states of affairs have to be understood. The state that is being negated (*the door is open*) and the actual state of affairs (*the door is not open*). It is herein assumed that in the first step of information processing, representations of both states of affairs are being constructed, whereas in the second stage of processing, the irrelevant representation is being suppressed. The hypothesis thereby accounts for the exaptation of inhibitory mechanisms in a functional manner.

Reconsidering the design introduced by Beltrán et al. (2018) and adapted by Montalti et al. (2023), a key change will be made in the following study. In only using action words as the target of sentential affirmation/negation, it is not possible to distinguish between the effects that are inherent to operational negation and the negation of a simulated action. Within the current study, two word stimuli (as in Montalti et al., 2023) will be used. However, not all stimuli will merit the simulation of a concept. To ensure this, in addition to 10 action words, 10 pseudo words will be presented as the target of the operational affirmation/negation.

If the employment of inhibitory mechanisms in fact stems from the necessary suppression of a simulated representation of the sentence, pseudo-words that do not elicit a simulation should mitigate the influence of the affirmation/negation. Therefore, all markers of motor inhibition should not differ significantly between the affirmative/negated condition.

If on the other hand, the recruitment of inhibition were to be an inherent property of the processing of negation, no matter the context, we should observe a similar influence of operational negation, independent of the action/pseudo word used as a target.

Demonstrating how the processing of sentential negation and motor inhibition are functionally akin might not only serve to instantiate the *neural-reuse hypothesis* but also serve as an explanation how the functional inheritance in *neural-reuse* is practically felicitous.

The Stop-Signal task that both papers employ as an experimental paradigm is a relatively novel one in the context of psycholinguistics, but a well established measure of inhibitory control in the realm of experimental cognitive psychology that offers a range of possible metrics.

Experiment 1

In the following study we aim to enhance our understanding of the processing of sentential negation by utilizing the physiological measure of response force exerted by our participants. In the Stop-Signal paradigm, participants perform a simple Go-Task that requires them to react to an unambiguous target cue. On some trials however, participants receive an additional (auditory) stop cue that requires them to inhibit their response. According to the Horse-race model (Band et al., 2003; Logan & Cowan, 1984; Logan et al., 1984) whether or not an answer is given on trials where a stop signal occurs is determined by an independent race between the activation elicited by the Go-target and the inhibitory activation elicited by the Stop-Signal. Whichever activation finishes the race first is the one that determines the outcome of each trial.

Initial accounts of this hypothesis were based on the assumption of a dichotomy of outcomes that is determined by the winner of the aforementioned race that is either a response is given, or no response is given. Recently however a myriad of studies were able to demonstrate that as like most dichotomies, this distinction appears to be a vast oversimplification of the real state of affairs. It has been shown (reliably so) that on trial where participants had reached the so-called *point of no return* and had given an erroneous response in the presence of an auditory stop-signal, the response force was attenuated compared to the response force in correct responses (Ko et al., 2012; A. T. Nguyen et al., 2020; T. V. Nguyen et al., 2021; Salomoni et al., 2023; Wang et al., 2023; Weber et al., 2024; Weissman & Schmidt, 2024) This demonstrates that there is at least a trichotomy of responses in the Stop-Signal task. *Correct responses*, *successful inhibitions* and *unsuccessful inhibitions*. This is not a distinction without a difference for at least two reasons. Firstly it demonstrates that inhibitory activation is invoked even when participants had already reached the previously dubbed *point of no return* and secondly because it demonstrates the sensitivity of response force measurements to the underlying mechanisms and suitability of physiological measures that are more fine-grained to investigate motor inhibition.

To this end, we conducted a first experiment that doesn't include any sentential material, in order to demonstrate our ability to detect correlates of motor inhibition in a Stop-Signal task through both behavioral and physiological measures.

Method

Participants

Apparatus and Stimuli

Procedure

Design

Results

Discussion

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Appendix