# *TRACING THE SECRETS OF HUMAN COGNITION*:

## SEMANTIC AND MOTORIC INHIBITION—SAME IN KIND OR DIFFERENT IN MIND?

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## Acknowledgments

Since the very first time I heard about cognitive control, I have been deeply intrigued by the concept: How can the information-processing in the human brain possibly vary adaptively and flexibly to such an extent within just milliseconds, what interactions take place, and of which detrimental consequences is impaired cognitive control the potential cause? For the opportunity to dive a bit deeper into this exciting, vast field, which led to the present study, I owe special thanks to my supervisor Tim Brennen—for your guidance, support, and encouragement throughout the whole process of planning the experiment, data collection, analysis, and writing. I also owe thanks to my co-supervisor André Sevenius Nilsen for programming the task, for valuable advice, patience, and perseverance during the writing, and above all during the preparation of the analysis process—your support has been outstanding. This thesis would not have been possible without the two of you. Your willingness to answer all of my questions, your passion for research, and your understanding of this student's life—that of writing a thesis, running a business, and taking care of a family, simultaneously—are greatly appreciated and have given me just the energy needed.

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# Abstract

***Author:***

***Title:*** Tracing the Secrets of Human Cognition: Semantic and Motoric Inhibition—Same in Kind or Different in Mind?

***Supervisors:***

***Author statement:*** The present study was an independent research project in which all data were collected and analyzed by the author.

***Background:*** Cognitive inhibition—the ability to stop or override a mental process—is an indispensable part of cognitive control in all humans. Impairments in this ability have been associated with a large number of conditions such as attention-deficit/hyperactivity disorder, psychopathology, substance abuse disorders, and obsessive-compulsive disorder. In a world with an ever-increasing importance of social interactions, understanding and inhibiting competing interpretations of words might be as important as inhibiting instinctual behavior. Thus, as the underpinnings of inhibition mechanisms still constitute a key question in current cognitive psychology and neuroscience, the present study aimed at shedding further light on this ability to suppress irrelevant information, more specifically, at investigating whether inhibition on a higher (semantic) level is the same as inhibition on a lower (motoric) level, or whether these are two distinct forms of inhibition mechanism. ***Methods***: A novel ambiguous word task was employed to investigate whether there is a difference in reaction time and/or accuracy in a task where alternative interpretations of homonyms were to be inhibited, simultaneously differentiating with more or less instinctive responses. A classic stop signal task was employed to explore any correlations between semantic inhibition and motoric inhibition. Reaction times and accuracy rates were collected from 40 participants. ***Results***: In sum, conditions involving homonyms showed the longest reaction times, for both shorter and delayed stimulus onset intervals, with the delayed interval resulting in the longest reaction time. The accuracy was slightly higher for the delayed interval compared to the shorter interval. No significant correlations could be observed between the stop signal reaction times in the stop signal task and the reaction times in the ambiguous word task in any of the analysis combinations performed. ***Conclusion***: The longer reaction times in conditions involving homonyms might be caused by the ambiguity inherent in homonyms, i.e. increased processing might reflect inhibitory processes, and a longer stimulus onset asynchrony potentially enables

the mechanism of inhibition to be activated. This could also account for the observed greater mean accuracy in the delayed interval compared to the shorter interval. As no significant correlations could be observed between the two tasks, we propose that motoric and semantic inhibition are two distinct forms of inhibition that potentially are not recruiting a single underlying mechanism, but to some degree have different neural correlates, although alternative interpretations are discussed. Given the importance of correct interpretation of language, the present study may serve as a tool for future research on cognitive processes in clinical conditions.

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*"I come constantly upon instances of how people start developing an argument sequence, perhaps rather tentatively, and reach a stage at which it is very much easier to go on than to go back. A little beyond this there comes a stage when, if they do make an effort to go back, they become hesitant, ineffective, and very often incoherent." Bartlett, 1958.*

# 1 INTRODUCTION

## 1.1 Cognitive control and executive functions

Every day, we face an enormous multitude of sensory inputs. We manage this myriad of inevitable stimuli by exercising cognitive control, through attention, perception, comprehension, and memory. Thus, virtually everything we do, and everything we feel or say, depends on our cognition—what we know, what we remember, how we behave, and how we think (Reisberg, 2010). In order to prevent a complete cognitive meltdown due to the simple fact that the brain has limited resources, the brain constantly has to choose one stimulus over another. Despite substantial theoretical and experimental progress during the past two decades on the underlying mechanisms of cognitive control and executive functions (Miller & Cohen, 2001; Koechlin & Summerfield, 2007), exactly how this type of contextual regulation occurs, and how this highly dynamic ability to coordinate, regulate, and sequence thoughts and actions in line with internal goals comes about, remains one of the greatest mysteries of human cognition; it constitutes a key question in current cognitive psychology and neuroscience research (Braver, 2012; Jiang, Heller, & Egner, 2014). One single idea seems to dominate whenever we are dealing with executive control, namely the notion that we need control processes to overcome behaviors that would otherwise be carried out in an automated way (Purves, Brannon, Cabeza, Huettel, & LaBar, 2008). Some neurologists, e.g., Marsel Mesulam, use the term *default mode* to define behavior that does not involve control processes (Purves et al., 2008). A typical example of a default mode would be the instinct to close your eyes in response to sharp light when you drive out of a tunnel. In order to overcome this automatic processing, several phenomena control the stream of information in the nervous system, above all the following: initiation, inhibition, task-shifting, and monitoring (Purves et al., 2008). Once a specific automatic or potentiated behavior has been inhibited, this paves the way for the selection of and transition to another behavior that seems more suitable in the context; hence, inhibition and initiation can be regarded as complementary phenomena in executive control, as the strength of some processes have to be altered relative to others in order for change to take place (Purves et al., 2008). Brain regions particularly involved in executive control are the dorsolateral prefrontal cortex and posterior parietal cortex, the ventromedial prefrontal cortex, the anterior cingulate cortex, and the basal ganglia (Lezak, 2004; Clark et al., 2008; Purves et al., 2008). Lack of cognitive control, and especially unintentionally focusing on irrelevant distractors, may hinder personal development and goals. Cognitive control also encompasses behavioral inhibition, or inhibition of automatic responses, which constitutes a major part of this study together with semantic inhibition. Deficits in such response inhibition have been linked to a great number of different disorders (Verbruggen & Logan, 2009) such as attention-deficit/hyperactivity disorder (Nigg, 2000; Oosterlaan, Logan & Sergeant, 1998), substance abuse disorders (e.g., Monterosso, Aron, Cordova, Xu, & London, 2005; Smith, Mattick, Jamadar, & Iredale, 2014), and obsessive-compulsive disorder (e.g., Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006). In many situations throughout our lives, there are numerous examples of the importance of response inhibition, and even survival may depend on a well-functioning ability to select one stimulus over another and process stimuli in a certain order of priority (Gazzaniga, Ivry, & Mangun, 2014), such as stopping yourself from crossing a street when a car comes around the corner without noticing you. All in all, inhibitory control warrants considerable attention because of its broad applications to diverse spheres of psychosocial functioning (Leotti & Wager, 2010), including, for instance, decision-making (Bechara, Damasio, & Damasio, 2000), emotion regulation (Ochsner, Bunge, Gross, & Gabrieli, 2002), psychological mechanisms related to attention (Schachar & Logan,1990), and social competence (Rydell, Thorell, & Bohlin, 2004).

## 1.2 What is cognitive inhibition?

In the vernacular, the term inhibition may appear to name a simple phenomenon, without much room for misinterpretation. It constitutes one of the core executive functions. However, empirical results suggest that not all inhibition is the same, and there is no agreement on the details when it comes to definition, conceptual levels, and potential psychological subdomains. According to Gorfein and MacLeod (2007), cognitive inhibition comprises two active ingredients, namely the stages of mental withholding and reduced performance. As to the framing, Gorfein and MacLeod (2007) distinguish inhibition on a neural and a cognitive (mental) level, the latter is also referred to as repression, restraining, or suppression (Gorfein & MacLeod, 2007). On a neural level, response inhibition is thought to involve the prefrontal cortex and basal ganglia (Noorani & Carpenter, 2014; Teichert & Ferrera, 2015), more specifically the hyperdirect cortico-striatal pathway (Teichert & Ferrera, 2015) and the inferior frontal gyrus (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003). Response inhibition is a critical aspect of motor and cognitive control (Aron, Robbins, &

Poldrack, 2014; Teichert & Ferrera, 2015). Damage to dorsolateral prefrontal cortex decrease cognitive control and motoric inhibition abilities, suggesting a specific localization and specific cognitive function in this particular area, e.g., Dimoska-Di Marco, McDonald, Kelly, Tate, & Johnstone (2011), found support for the notion that response inhibition deficits follow traumatic brain injuries in adults. Studies of event-related potentials with participants in response inhibition tasks like go/no-go and stop signal tasks have also shown that both conflict and inhibition strongly affect the N200 and P300 brain responses, overall results suggesting that the P300 primarily represents motor inhibition, whereas the N200 predominantly reflects conflict-related effects (Enriquez-Geppert, Konrad, Pantev, & Huster, 2010). Despite advances in the past two or three decades concerning cognitive processes, there is no consensus on how inhibition should be defined in terms of cognition. Inconsistent conceptualizations and ambiguous operationalizations have led to several mental processes receiving notoriously “fuzzy” terms with no consensus. To quote Colin M. MacLeod (Gorfein & MacLeod, 2007): “Everyone knows what inhibition is—and that creates a very real problem.” Gorfein and MacLeod (2007) suggest the following definition, which provides the basis throughout this paper: *Cognitive inhibition is the stopping or overriding of a mental process, in whole or in part, with or without intention.*

Figure 1 shows some of the main types of inhibition related to neuroscience and psychology.

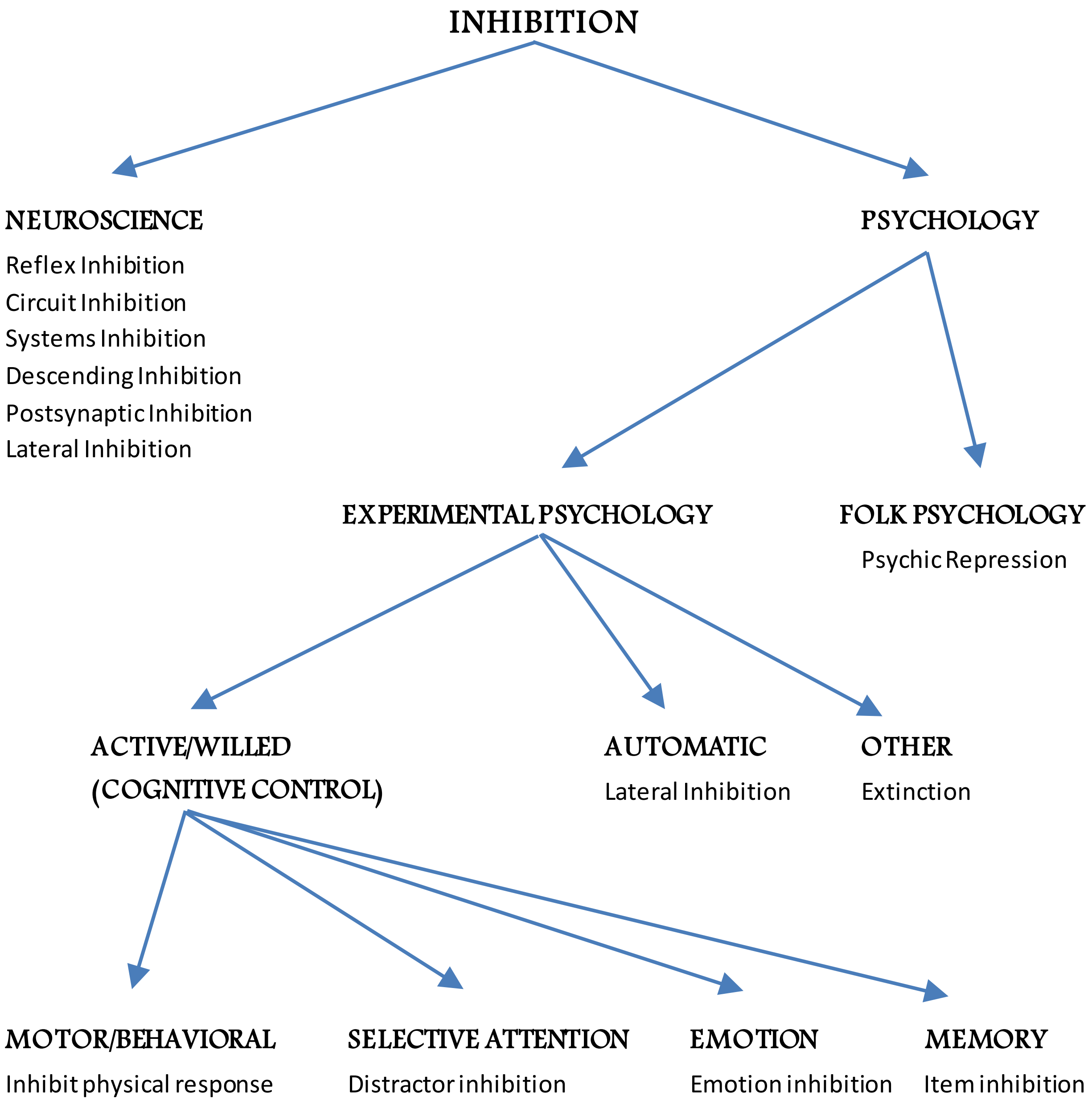

*Figure 1.* Inhibition in neuroscience and psychology (schematic based on Aron, 2007, Fig. 2)

The present study will be concerned with two forms of inhibition mentioned above, semantic inhibition and motoric (behavioral) inhibition. Inhibitory control is typically measured by neuropsychological tests to assess individuals' ability to override their habitual or dominant motoric/behavioral response to a given stimulus (e.g., Diamond, 2013; Houdé & Borst, 2014).

When it comes to semantic inhibition, prior presentation of stimuli related in meaning (semantic) to a target affects the accuracy and speed of the processing of the target (Howard, Nickels, Coltheart, & Cole-Virtue, 2006). The nature of this effect varies according to the task requirements, the time interval between the items presented, and the modality of presentation (Howard et al., 2006). This phenomenon is commonly measured by using tasks involving sentences and words with lexical ambiguity (e.g., Copland, Sefe, Ashley, Hudson, & Chenery, 2009). Motoric—behavioral—inhibition can be described as the deliberate control of a primary motor response in compliance with changing context cues (Nigg, 2000) and is typically measured by the Go-/No-go task, the Stop signal task, and the Flanker task, developed in different variants.

The Stop signal task was introduced by Lappin and Eriksen in 1966 and further developed by Logan and colleagues. The stop signal paradigm is most suitable for the study of response inhibition in laboratory settings, and has become increasingly popular in the fields of cognitive neuroscience, cognitive psychology, and psychopathology (Verbruggen & Logan, 2008).

Stop signal performance is typically described as a horse-race-model between a go process, triggered by a go stimulus, and a stop process, triggered by a stop signal (Logan, Cowan, & Davis, 1984), and constitutes a two-alternative forced choice task. Response inhibition depends on the relative finishing time of these two processes (Verbruggen & Logan, 2009). The stop signal reaction time (SSRT) in particular constitutes a critical measure of the cognitive control processes involved in stopping (Verbruggen & Logan, 2008, 2009) and allows an estimate of the covert latency of the stop process (Verbruggen, Chambers, & Logan, 2013). In simpler terms, it describes the time it takes for a person to suppress a response after a stop signal has been presented (Verbruggen & Logan, 2008, 2009). Subjects are thought to inhibit responses with higher efficiency with a shorter SSRT. Moreover, the stop signal delay (SSD) is the time from the initial go stimulus to the stop signal, and is varied to manipulate the probability of inhibition (Bissett & Logan, 2011). With shorter SSDs, subjects usually inhibit their responses, and as SSD increases, the probability of inhibition decreases. Short SSDs bias the race in favor of stopping, and thus increase the probability of inhibiting, whereas long SSDs bias the race in favor of going and thereby increase the probability of responding (Bissett & Logan, 2011). Figure 2 is a graphical representation of this Horse Race model.

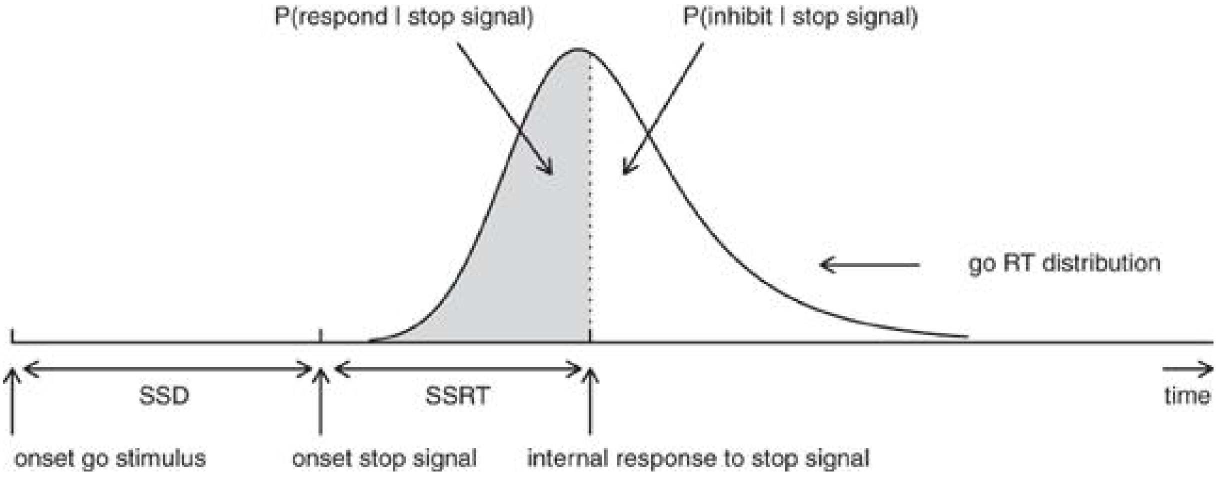

*Figure 2*. Graphical representation of the Horse Race Model. SSRT = stop signal reaction time, SSD = stop signal delay, P(respond|stop signal) = probability of responding on stop signal trials. Description and illustration courtesy, Matzke, Dolan, Logan, Brown, & Wagenmakers, 2013.

It has been shown that the brain activity of several different regions in the frontal cortex correlates negatively with SSRT (the shorter the SSRT, the greater the brain activity in these regions) (Li, Huang, Constable, & Sinha, 2006; Li, Yan, Sinha, & Lee, 2008).

In order to measure semantic inhibition, we designed a task involving homonyms, as alternative interpretations of homonyms might interfere with semantic interpretation of the meaning of a sentence. This task extrapolates on an earlier study performed by Gernsbacher, Varner, & Faust (1990) and is described further below.

## 1.3 Previous research

Recent findings (Streb, Mecklinger, Anderson, Johanna, & Michael, 2016) in which “traumatic” films were used as stressors suggest that deficient retrieval suppression is a potential risk factor for developing intrusive memories after traumatic events, constituting another very important reason why the phenomenon of inhibition should be further investigated. More specifically, people with good retrieval suppression abilities had less distressing intrusive memories after watching the films, whereas poor retrieval suppression was associated with persistent distressing intrusions and post-traumatic stress disorder (Streb et al., 2016). In general, how we choose one action over another has intrigued neuroscientists for decades (Noorani & Carpenter, 2014). Despite the complexity of the topic and the constant interactions between different cortical and subcortical structures and neuronal ensembles in the brain, mirroring the central problem in cognitive science, namely how the cognitive system modulates the accessibility or activation of information in real time towards thought and action (Gorfein & MacLeod, 2007), several attempts have been made to gain a better understanding of the underpinnings, amongst others an approach that assumes a set of cognitive control processes that cooperate to either *enhance* or *inhibit* task-related processes (Gorfein & MacLeod, 2007). Among these are Stroop color naming (MacLeod, 1991; Spieler, Balota, & Faust, 1996), inhibition of return (Faust & Balota, 1997; Posner & Cohen, 1984), and task switching (Mayr & Keele, 2000). Miyake et al. (2000) investigated the three often-postulated executive functions, namely mental shifting, information updating and monitoring, and inhibition of prepotent responses and their roles in complex executive tasks ("frontal lobe-related"). Factor analysis and structural equation modeling indicated that these three are moderately correlated, yet clearly separable, and, importantly, contribute differentially to performance on complex executive tasks (Miyake et al., 2000). Moreover, the results demonstrate that it is important to recognize both the diversity and the unity of these functions, and that latent variable analysis can be a useful approach to studying their organization and roles (Miyake et al., 2000). In the past, studies have been conducted to measure performance on different scales in skilled versus less skilled comprehenders with regard to inhibition and suppression mechanisms (e.g., De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Wagner, 2002; Cartoceti & Abusamra, 2012). Gernsbacher, Varner, and Faust (1990) performed a study on differences in general comprehension skills. Based on their Structure Building Framework, suggesting three structure building processes, namely the laying of a foundation for a mental structure, mapping of coherent information onto this developing structure, and shifting to initiate a new structure or substructure when the incoming information is less coherent, and two separate mechanisms where some memory cells are enhanced and others are suppressed (Gernsbacher, Varner, & Faust, 1990), they tested the hypothesis that less skilled comprehenders are less able to suppress contextually irrelevant information, and found support for this notion. More specifically, according to the authors, the consequences of a less efficient, or perhaps simply less rapid, suppression mechanism would be that inappropriate information remains activated, and due to the fact that this information cannot be mapped onto the existing developing structure, its activation might lay the foundation for a new substructure (Gernsbacher, Varner, & Faust, 1990). This, in turn, would lead to less skilled comprehenders' greater tendency toward shifting. Although much has been said and written about the utility of inhibition as such in our persistent attempt to explain the processes involved in cognition (e.g., Neill & Valdes, 1996; Burke & College, 1997; Pratt, Spalek, & Bradshaw, 1999), the vast majority of existing data really seems to be best understood in terms of inhibition mechanisms (Gorfein & MacLeod, 2007). However, several questions have been raised, e.g.: To what extent can different functions that are often attributed to the frontal lobes or to the central executive be regarded as unitary in the sense that they are reflections of the same underlying ability or mechanism (Miyake et al., 2000)? Clinical observations show some evidence for the non-unitary nature of frontal lobe or executive functions (Baddeley, 1996; Miyake et al., 2000), for example, some patients seem to fail on one type of executive tasks, but not on others (e.g., shifting, inhibition, and updating), or they may show an opposite pattern, indicating that executive functions may not be completely unitary (Miyake et al., 2000).

The process of reading requires a large number of complex cognitive operations that proceed within a fraction of a second, and a given letter sequence has to be related to its respective semantics and phonology and integrated as information in order to comprehend a continuous text (Schuster, Hawelka, Hutzler, Kronbichler, & Richlan, 2016). The length, frequency, and predictability of a word are among the most influential known visuo-orthographic, lexical, and contextual processing factors involved in visual word recognition (Rayner 1998, 2009; Schuster et al., 2016). A study on word length effect on lexical decision reaction times in a large-scale study based on the English Lexicon Project showed that word length affects response times in a curvilinear fashion (New, Ferrand, Pallier, & Brysbaert, 2006) such that, specifically, medium-length words (i.e., 5–8 letters) elicited the shortest response times, while short (i.e., <5 letters) and longer words (i.e., up to 13 letters) elicited comparatively longer response times (Schuster et al., 2016). Substantiating this notion, Yarkoni, Speer, Balota, McAvoy, & Zacks (2008) showed that word length influences activation in different brain regions in a curvilinear fashion (Yarkoni et al., 2008; Schuster et al., 2016). Among these regions, a region of left occipital-temporal cortex, also named the visual word form area (VWFA) (Shuster et al, 2016; Vogel, Petersen, & Schlaggar, 2014), exhibited a U-shaped modulation by eliciting the least activation to words with a medium length (Schuster, et al., 2016). This means that the VWFA preferentially responds to words that have an “optimal” length, meaning that they can be more efficiently processed, and this is then mirrored by reduced activation (Yarkoni et al., 2008; Schuster et al, 2016). Inhibition may also be closely related to conflicts between automatic reactions and the intention to control, the well-known system 1 and system 2 thinking, where system 1 represents automatic, quick, and effortless thinking, and system 2 constitutes the more deliberate, considered, and rational thinking (Kahneman, 2011).

To our knowledge, previous research has not addressed the question of whether there is a relationship between inhibition on a higher (semantic) versus lower (motoric) level, and a Norwegian equivalent of the task in Experiment 4 in Gernsbacher, Varner, and Faust (1990) does not seem to exist. Using that task as a partial basis, we constructed a new task, in Norwegian, that lets us control for sentence and word length, accommodate differences in how long it takes to understand the sentences, and isolate the relationship between probe and target. We also adjusted the delay parameters. The eventual final cues, probes, and targets in our task underwent several minor changes. In general, potential effects of homonyms in situations where time and accuracy play a crucial role seem to be a somewhat neglected field. Hence, while standing on the shoulders of previous researchers within the vast field of cognitive control, this study aims at shedding new light on the intertwined processes involved in cognitive inhibition. The hypotheses described in the next subsection serve as the main foundation.

### 1.4 Hypotheses and predictions

To elucidate the underpinnings of inhibition mechanisms as such and the brain's ability to suppress irrelevant information, we chose a novel semantic inhibition paradigm. The paradigm extrapolates from the above-mentioned study by Gernsbacher, Varner, and Faust (1990, Experiment 4). In that experiment, the participants were presented with a sentence followed by a test word with a time delay (100 ms or 850 ms) between the sentence and the word. The participants' task was to verify if the test word matched the meaning of the sentence. The test word matched the meaning of the sentence on half the trials. On half of those trials, the last word in the sentence was ambiguous, and the test word was a meaning of the ambiguous word that was not appropriate in the context (Gernsbacher, Varner, & Faust, 1990). The researchers compared how rapidly the participants responded that the test word was not related to the sentence in the two cases, when the last word of the sentence was unambiguous, and when it was ambiguous in such a way that the test word was related to one of its meanings, but not the one used in the sentence. With this comparison, they obtained a measure of how activated the inappropriate meaning of the ambiguous word was (Gernsbacher, Varner, & Faust, 1990; Wagner, 2002). The slower the (correct) rejection of the test word, the poorer the ability to suppress the inappropriate meaning must have been:

*He dug with the shovel*

→ *Ace*

*He dug with the spade*

→ *Ace*

At the shorter interval (100 ms), less and more skilled comprehenders experienced the same amount of interference from the ambiguity; however, with a delay of 850 ms, more skilled readers no longer showed a significant amount of interference, i.e., no priming effect could be observed at this interval (Gernsbacher, Varner, & Faust, 1990; Wagner, 2002), perhaps due to the suppression mechanism. The task in our study constituted a variant of this task.

To investigate how semantic inhibition relates to behavioral/response inhibition, we employed a second test, a version of the classic stop signal task. In the task, the participants are asked to respond to the geometrical shape of the stimulus, presented on the screen as either a square or a circle. In 25% of the trials, an auditory signal representing a stop signal is presented, indicating that all responses should be withheld. Based on the two mentioned tasks, and the above-mentioned findings, the present study aims at investigating the following two hypotheses (hereinafter $H_1$, $H_2$):

$H_1$: Answering on semantic-related tasks involving ambiguous words (homonyms) requires a high degree of cognitive effort; hence, subjects' inhibition abilities in this context should be mirrored by significant differences in reaction times (RTs) and accuracy, based on conditions and stimulus onset asynchronies (SOAs), more specifically, an incongruent unambiguous condition and an incongruent ambiguous condition. Subjects should also have longer reaction times when answering correctly on tasks with ambiguous words than when answering correctly on tasks with unambiguous words. Confirming a statement with a "Yes," potentially as part of automatic processing, requires less cognitive effort than disconfirming as this presupposes an internal dialogue and a more thorough consideration of the task. Anticipated cognitive demand plays a significant role in behavioral decision-making (Kool et al., 2010), and people are prone to follow the "law of least mental effort" (Kool et al., 2010). This applies especially when people are subject to time pressure. The variable of interest is not the reaction time as such, but the difference in reaction time between the incongruent ambiguous and the incongruent unambiguous condition. Following this notion, people should also respond faster on congruent than on incongruent trials. The accuracy should also be mirrored correspondingly by the same variables. In order to shed further light on any correlations between gender and accuracy, handedness and accuracy, stress and accuracy, and the tendency to confuse words and accuracy in the ambiguous word task, an administered questionnaire (Appendix III) will be drawn on to obtain exploratory results.

In sum, we hypothesize that the incongruent ambiguous condition in a novel ambiguous word task will show longer reaction time than the incongruent unambiguous condition.

***$H_2$***: Based on existing literature about various forms of inhibition, especially inspired by the mentioned study by Gernsbacher, Varner, and Faust (1990) and also Miyake et al. (2000), on the one hand, and the apparent lack of correlation studies of inhibition on different levels, on the other, we hypothesize that inhibition on a higher (semantic) level and inhibition on a lower (motoric) level are two distinct forms of inhibition mechanism. To take a closer look at these phenomena of initiation and inhibition and how these processes at some point can no longer be stopped, which yields a template for the different measures of the inhibition paradigm and thus also paints a clearer picture, a version of the classic stop signal task will also be drawn on. The above-mentioned ambiguous word test represents the higher level, whereas the stop signal task, described further below, represents the lower level in this context. We hypothesize that there will be no significant correlations between the reaction times in the ambiguous word task and the stop signal reaction times in the stop signal task. Moreover, if the hypothesis can be supported, there should also be no significant correlations between the *reaction times* in the stop signal task and the overall reaction time across conditions and stimulus onset asynchronies in the ambiguous word task.

In sum, we hypothesize that inhibition on a higher (semantic) level and inhibition on a lower (motoric/behavioral) level are two distinct forms of inhibition mechanism. Results will be obtained by correlating the reaction times from the novel ambiguous word task with the stop signal reaction time in a classic stop signal task.

# 2 Methods

## 2.1 Ethics

It was unnecessary to obtain ethical consent for this non-health-related, non-intrusive project, with no identifying information collected. As all participants were above the age of majority according to Norwegian law (18), no further approval was required. As the electrical equipment in this study only involved a PC and a monitor and did not involve known radiation, X-rays, or any type of deceptions, a project risk management plan was not required nor any further measures. Upon arrival, the participants signed a participant consent form from the Department of Psychology. The participants were debriefed at the end of the second (final) part of the test.

## 2.2 Participants

The participants, 45 adults ($N_{\text{females}} = 30$), mean age 29, range 19-54 (*SD* = 9.54), were recruited through posters at the Department of Psychology and direct request on the campus at the University of Oslo as well as through acquaintances. Inclusion criteria were age ≥ 18 and either Norwegian as a first language or simultaneous or successive early bilingualism. Exclusion criteria were previous epileptic seizures. While some studies show a different neurological architecture for left-handed individuals that could potentially confound results, handedness was not regarded as a sufficient exclusion criterion in this context, but rather as a possibly confounding variable of interest.

## 2.3 Equipment and Stimuli

In this experiment, designed as a within-subject study, the stimuli consisted of two different tasks, namely a version of the stop signal task, and an ambiguous word task. Both tasks were presented on an ASUS PC monitor, display size 34.5 cm by 19.5 cm. The screen parameters had default values with a refresh rate of 60 Hz, a color depth of 32, and 1024 x 768 pixels. Prior to participation, the participants received information about the study's objective with regard to inhibition as a phenomenon in cognition, but were naïve to the specific hypotheses and tasks.

In order to construct the ambiguous word task, a sentence list had to be generated. Sentences and words (below described as cue, probe and target words) were constructed by searching for homonyms from online sources and in other literature (if, e.g., a word had been applied as a homonym in one context in the sentence list, it was not used as a homonym in another context; it could, however, be applied as part of a sentence). Prior to the implementation of the sentences in the program, a frequency analysis of the probe/target word in the sentence list was conducted by using the online Lexicographic Corpus for Norwegian Bokmål, offered by the Text Laboratory, Department of Linguistics and Scandinavian Studies, University of Oslo.

Prior to the main study, a pilot study (Appendix II) in the form of a stop signal task and a variation of the ambiguous word task was performed. This small-scale rehearsal of the main study was conducted specifically to test the feasibility of the participant procedures, the intelligibility of the instructions given on the screen prior to each participant session, the quality of the sentence list, and generally testing the paradigm as such, taking into account feedback from the participants. In order to avoid any contamination, data from the pilot study were not included in the main study, nor were participants from the pilot study included in the main study. The pilot study revealed some areas with room for improvement that led to modifications in the main study: 1) The stop signal task with target arrows was replaced by a version that was considered better and more proper, with squares, circles, and an acoustic stop signal. 2) The instructions in the ambiguous word test had to be edited due to being too elaborate and detailed; the initial intention of wanting to be clear and concise to avoid any confusion or confounding effects had the opposite effect. 3) No questionnaire was provided beforehand, unlike in the main research design. Based on the spoken Norwegian of each participant, it was assumed they were all native Norwegian speakers, an assumption that for one of the participants turned out not to hold true. This was discovered as the participant reported problems understanding some of the words in context, thus causing potential confounding variables with several possible outcomes, namely no effects, subtle effects, or more severe distortions of the results. Hence, only native speakers of Norwegian were included in the main study.

Prior to the day of the experiment, the participants received a link to a short questionnaire (via survio.com) with general questions about education level, subjectively perceived stress, energy level, eating habits and diet, and other factors that were regarded as potentially relevant in this context. The questionnaire served as a purposeful control measure in this context to disclose potential patterns. For anonymity, the questionnaires did not include names or participant numbers, only the time and date of the experiment, which led to two questionnaires having to be excluded due to insufficient detail.

Because of the importance of word length, in addition to the frequency analysis, the number of letters in the probe/target words/homonyms in the three potential combinations (see Appendix I, Sentence List) was also analyzed in the form of paired samples t-tests. Example: De svømte i havet så ofte de… kunne - ville (= homonym) – gale. The sentences in the sentence list had a mean number of letters of 22.6 (*SD* = 8.25). Word 1 had a mean letter count of 5.08 (*SD* = 1.29); word 2 had a mean of 4.4 letters (*SD* = 1.22); and word 3 had a mean of 5.25 (*SD* = 1.66). T-tests of the lists with word 1 and word 2 showed significance with $p = .001$; the list with word 2 vs. word 3 had a significance level less than .001, whereas there was no significance in the combination of word 1 and 3 ($p = 0.5$). As to the frequency analyses based on the Lexicographic Corpus for Norwegian Bokmål, the mean frequency of words used as word 1 in our context showed a mean of 11.610 (*SD* = 30.571); the same procedure for the lists for words 2 and 3 resulted in means of 8.560 (*SD* = 21.361) and 3.992 (*SD* = 15.272), respectively. The results of the frequency analyses made us replace some of the words in the sentence list. However, the very large differences in means and large standard deviations in frequency were expected and did not lead to further measures. Also, some “critical” sentences that still remained were revised by friends and acquaintances with regard to semantics and to evaluate whether external people would have the same sensation of ambiguity as we did. More specifically, they were asked if they could observe an immediate correlation between the presented words, and if the sentence had a content that made semantic sense. The sentence list was revised, edited, and complemented based on the findings.

### 2.3.1 Stop Signal Task

The first part of the experiment was conducted using the stop signal task STOP-IT, published by the University of Exeter (issued March 21, 2013), funded/sponsored by the National Science Foundation, and developed by Verbruggen. The subjects were to respond to the geometrical shape of the stimulus, presented on the screen as either a square or a circle. In 25% of the trials, an auditory signal representing a stop signal was presented, indicating that all responses should be withheld. To control for fast responding over correct stopping in the stop signal task, i.e., a speed-accuracy trade-off, and also to prevent strategies to withhold responses, the staircase method was implemented in the program, continuously adjusting the stop signal delay (SSD), which was initially set at 250 ms, with a tracking procedure to assure a probability of stopping of 0.5. SSD was decreased by 50 ms if the participants failed to inhibit their response (making the next stop trial more easy), and increased by 50 ms if the participants succeeded in inhibiting their response (making the next stop-trial more difficult).

Figure 3 is a schematic representation of the experimentation procedure in the stop signal task.

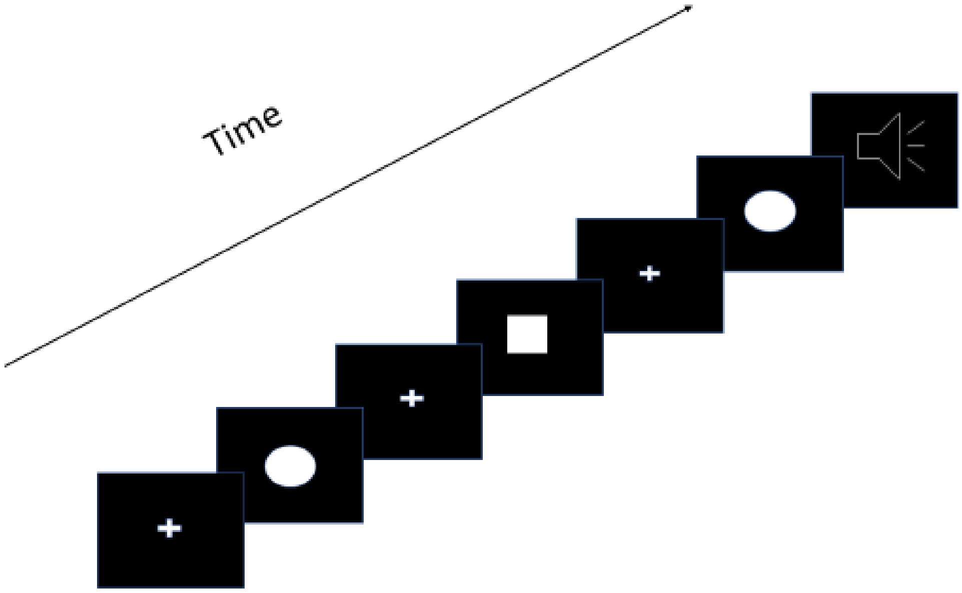

*Figure 3*. Schematic representation of the experimentation procedure in the stop signal task with go trials and a stop trial.

The stimuli are presented in white in the center of the screen on a black background, in full-screen mode. Each trial starts with the presentation of a fixation sign (+), which is replaced by the primary-task stimulus, namely a square or a circle, after 250 ms. Occasionally, an auditory stop signal (750 Hz) is presented for 75 ms shortly after the stimulus onset. The stimulus remains on the screen until the participant responds, or until a maximum presentation time of 1250 ms. The interstimulus interval is independent of reaction time and set to 2000 ms. On stop signal trials, a stop signal is presented after a variable SSD. The responses are still registered during presentation of stop signals.

### 2.3.2 Ambiguous Word Task

The second part of the experiment, the ambiguous word task, was presented using E-Prime 2.0.10 Professional Software. The task consists of one block with 72 trials with sentences lacking one word, namely the last word, to make them semantically meaningful sentences. More specifically, each trial starts with a fixation cross for 100 ms (visual angles were not fixed in this study as each participant adjusted the distance to the screen to obtain the most convenient and comfortable distance). A sentence is then presented, and the participant can proceed as soon as he or she presses a button, indicating that the sentence is understood. A "single" word is then presented after 200 ms and remains on the screen for 500 ms. Depending on the stimulus onset asynchrony (SOA), a "last" word is presented after 250 ms or 750 ms, for 500 ms, followed by a blank screen for 2,000 ms. The participant must give their response within 2,500 ms (target and blank screen).The participant receives feedback with correct / uncorrect / missing response for 1,500 ms. Each single word (presented in between the sentence and the so-called last word) can be either ambiguous or non-ambiguous. The ambiguous words are homonyms for which one interpretation fits the context of the (incomplete) sentence and another does not. Each of the last words can either have a thematic relation (i.e., fit semantically) to the sentence, or to the previous single word, or both, here referred to as incongruent and congruent. Hence, each trial can be thought of in terms of three elements: cue, probe, and target, cue representing the context to the participant (the incomplete sentence due to one word missing), probe as a modulator of the target (the first of the two words following the sentence; what we called the "single" word, above), and the target (the second word immediately following the first word; what we called the "last" word, above). This gave us four possible conditions, and in one of these conditions, the target has a semantic relation to the irrelevant meaning of the probe. An example from a trial would be "Jan reddet hunden fra elva og ble erklært en…" followed by the word "stjerne", then again the word "helt". In this case, the answer is correct if the participant responds with Yes. If, however, the same sentence is followed by the target word (second single word) "komplett", the correct answer would be No, as "komplett" would not be semantically consistent with the sentence in this context, but it would be linked to the probe word "helt" which is a synonym to "komplett" when interpreted alternatively. Thus, what makes the task difficult for the participants is the fact that the probe and the target in some trials are related in a way that causes confusion, and the decision has to be made within a very short time (also causing some of the participants to develop strategies, e.g., looking away as the probe appears on the screen). The shorter the interval (stimulus onset asynchrony, SOA) between the probe and the target, the more difficult the task grows. The following example provides a specific overview of the four conditions (trial types). Congruent ambiguous: Grete Waitz var en dyktig… *probe*: løper, *target*: utøver. Incongruent unambiguous: Grete Waitz var en dyktig…*probe*: utøver, *target*: teppe. Incongruent ambiguous: Grete Waitz var en dyktig… *probe*: løper, *target*:

teppe. Congruent unambiguous: Grete Waitz var en dyktig… *probe*: utøver, *target*: løper. As can be seen, the congruent unambiguous and congruent ambiguous conditions above represent a similar trial where the participants should answer Yes, as there is a link between words and sentences. The incongruent unambiguous condition and the incongruent ambiguous conditions represent trials where the participants should answer No, as there is either no link between words and sentence, or, in the latter case, a link between words, but not with the sentence. The comparison of interest to the hypothesis is that between the incongruent ambiguous condition and the incongruent unambiguous condition.

Table 1

*Combinations of the Probe and Target and the Resulting Conditions*

| Probe | Target | Condition |
|---|---|---|
| Homonymous | Congruent | Congruent ambiguous (“Condition 1”) |
| Homonymous | Incongruent | Incongruent ambiguous (“Condition 3”) |
| Non-homonymous | Congruent | Congruent unambiguous (“Condition 4”) |
| Non-homonymous | Incongruent | Incongruent unambiguous (“Condition 2”) |

Figure 4 is a schematic representation of the experimentation procedure in the ambiguous word task.

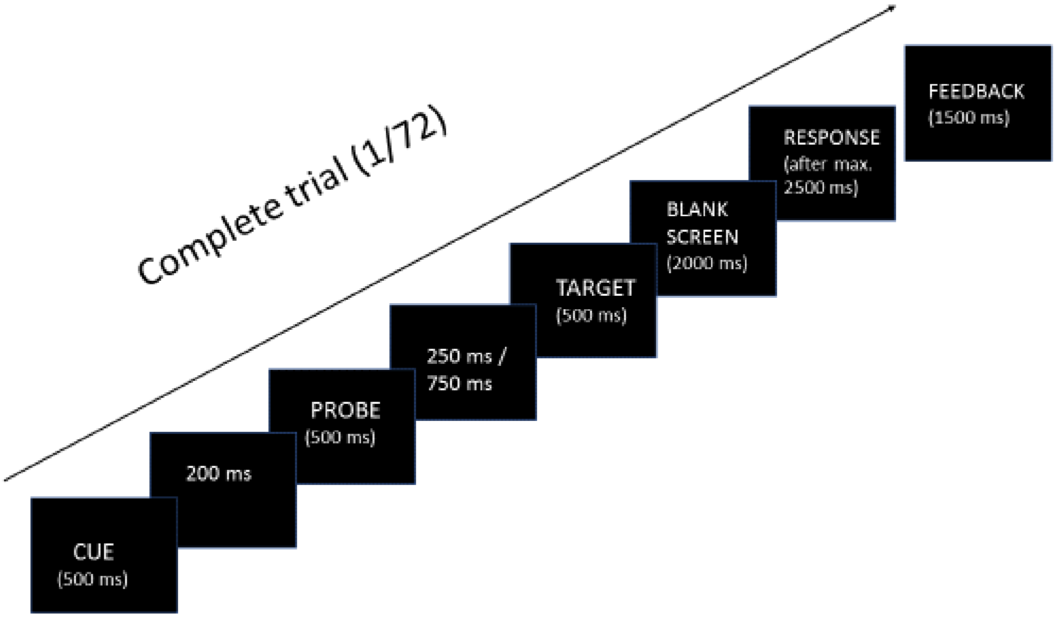

*Figure 4.* Schematic representation of the experimentation procedure in the ambiguous word task with a complete trial.

The participants were urged to press a specific key on the keyboard representing “Yes” if the target word was semantically consistent with the sentence. In the conditions where the target word had a thematic relation to the irrelevant meaning of the ambiguous word, answering “No” would require a higher degree of cognitive effort. This cognitive effort was registered in the form of response time and error rates. Half of the trials were related sentences; however, as in the Gernsbacher study, we were more interested in the trials where the last test word was *not* semantically consistent with the sentence

In order to enhance statistical validity, the lists were pseudo-randomized in four different conditions with an equal number of sentences in each condition and no more than three sentences with the same condition in succession. Hence, the sequence is not randomized across participants. This means that each sentence was randomly allocated to the four different conditions, but with equal numbers in each group. The randomization was repeated until a maximum of three sentences of the same type followed successively. Four alternate lists were computed so that each sentence was represented with each condition across the four lists ensuring no sequencing effects due to the order of trials and conditions. This minimizes the effects of the sequences with regard to the condition for each participant and the effect across participants for the sentence-condition combination.

## 2.4 Procedure

Participants were told what the project was about and what the tasks involved, and they were asked to sign a consent form upon arrival, after which they received general information about the project and were told they could expect it to be completed in approximately 20 minutes (depending on potential questions). They were also offered a glass of water (to avoid thirst as a potential confounding variable). Participants were seated comfortably on a chair in a sound-attenuated room in front of the PC and instructed to give their answers manually on the PC keyboard using their index fingers on both hands. The distance between the participant and display monitor was not fixed, giving each participant the opportunity to adjust the distance to that most comfortable and convenient. The speakers were always set to 70%. If the stimulus in the first task, namely the stop signal task, was a square, the subjects were requested to press the key on the keyboard marked with a colored patch with a square; in the other case, they were requested to press the key marked with a colored patch with a circle. Participants were instructed to give their answers as accurately and as fast as possible. The experiment started with a practice block of 32 trials to make sure the participants had understood the task, followed by 3 experimental blocks of 64 trials each. The auditory stop signal was presented after a variable delay, the so-called stop signal delay. Participants were asked to inhibit or withhold their response when they heard the auditory stop signal. Participants received information on the screen about their performance immediately after each block. The next block always started 10 seconds after the previous block was finished. Information was provided about the number of incorrect responses (related to no-signal trials), the number of missed responses, and the mean reaction time. Further, information about the correctly suppressed responses was provided as a percentage (related to stop signal trials). As soon as the stop signal task was finished, participants proceeded with the second (and final) part of the experiment, namely the ambiguous word task.

In the ambiguous word task, as in the first part, participants received instructions on the screen and from the researcher. As in the SST, participants were instructed to answer as fast and as accurately as they could. The task started with three practice trials to ensure that the participants had understood the task, and they were encouraged to ask any questions.

When they were sure they had understood the task, they were urged to press any key to start the first trial. The first sentence was then presented, and they were requested to continue by pressing the space bar to display the first word as soon as the sentence was understood. Shortly after, another word appeared on the screen. The word could either have a thematic relation to the previous sentence, or to the previous, single word, or to both. Participants were urged to press “A” (representing Yes) if the word was semantically consistent with the sentence, and “K” (representing No) if the word was not semantically consistent with the sentence.

## 2.5 Data cleansing and preprocessing

Prior to the analyses, measures were taken according to common procedures for cleansing and preprocessing as follows: In the stop signal task, as presupposed by the staircase method, an overall 50% accuracy on stop signal trials for each individual is required to be considered in the analyses. Due to a significant deviation from this requirement, two subjects were excluded from the stop signal task. Further investigation revealed that their performance deviated throughout the experiment; in one of the subjects, these findings were probably due to program errors in the last experiment block. Further, in the ambiguous word task, incorrect trials were filtered out and excluded from subsequent analyses. Trials with RT<100 ms were discarded across conditions, lists, and SOAs, based on previous research showing that genuine reaction times have a minimum of 100 ms (cutoff normally between 100-200 ms); reaction times below this range could be indicative of non-deliberate responses and are below the common conception of the time span needed for human stimulus perception and motor responses (Whelan, 2008). In line with common procedures for motoric/behavioral tasks, only subjects with an overall accuracy ≥70% in the ambiguous word task were considered further in the analyses. Three subjects failed to meet this criterion and were therefore excluded. Hence, of the original 45 participants, 40 were considered in the analyses. This sample size was still assumed to give sufficient statistical power to monitor potential differences and make it possible to discern potential task-related differences in the analysis of the two tasks. Table 2 gives an overview of the main variables and inclusion criteria in both tasks (results and participants not complying with the above-mentioned requirements were removed prior to analysis of the sentence lists and their combinations).

Table 2

*Overview of the Experiments with Tasks and Variables*

| **Participants** | | **Inclusion criteria** |
|---|---|---|
| $N = 40$ ($N_{\text{females}} = 26$) | | Age ≥18, no epileptic history, native Norwegian speaker / simultaneous or successive early bilingualism |
| **Experimental Tasks** | | |
| *Stop Signal Task* | | Correct trials |
| | | SSRT>100 ms |
| SSRT | | Correctness ~50% |
| RT | | |
| *Ambiguous Word Task* | | Correct trials |
| | | RT>100 ms |
| | | Correctness ≥70% |
| RT | | |
| ACC | | |
| Condition (trial type): | Congruent, ambiguous | |
| | Incongruent, ambiguous | |
| | Incongruent, unambiguous | |
| | Congruent, unambiguous | |
| SOA: | 250 and 750 ms | |
| **Appendices** Appendix I: | Sentence List | |
| Appendix II: | Pilot Study | |
| Appendix III: | Questionnaire | |

SSRT = Stop Signal Reaction Time; RT = Reaction Time; SOA = Stimulus Onset Asynchrony 250 milliseconds and 750 milliseconds; ACC = Accuracy

## 2.6 Statistical analyses

Statistical analyses were performed by using IBM SPSS Statistics 24. Variables were based on reaction time (RT) in the ambiguous word task, stop signal reaction time (SSRT) and reaction time for correct go-trials in the stop signal task, and accuracy-rate data. For all tests, the significance threshold was set at .05. The following procedure will be used to obtain a measure of semantic inhibition in this context: $(RT_{\text{ambiguous}} - RT_{\text{unambiguous}})_{\text{incongruent\_250}} - (RT_{\text{ambiguous}} - RT_{\text{unambiguous}})_{\text{incongruent\_750}}$, where only reaction times for correct responses, including correct rejections, are included and considered further in the analysis. The results obtained from each separate individual are subsequently correlated with the results from the stop signal task.

Mean reaction times were analyzed in the different conditions (described above). As normal to approximately normal distributions are a prerequisite for further tests, Shapiro-Wilk tests were performed for both tasks, and t-tests and one-way analyses of variance (ANOVA) were performed to identify rates within and across gender to unveil any gender-related results in potential post hoc analyses.

As to the stop signal task, stop signal reaction times were computed from the stop signal data. The task has a within-subject single measure design. The results were analyzed with ANALYZE-IT, a program that allows estimation of the stop signal reaction time for every participant and calculates the mean values for all dependent variables of interest (Verbruggen & Logan, 2008, 2009).

Reaction times in the ambiguous word task were analyzed in a 2 x 2 repeated measures ANOVA, with SOAs and conditions as within subject factors, levels 250 ms and 750 ms (SOA), and incongruent ambiguous and unambiguous conditions. F-ratios with $df_{\text{effect}}$ and $df_{\text{error}}$, significance levels ($p$-values), and partial eta squared ($\eta p^2$) are reported (as this is a repeated measures design, the omega squared ($\omega^2$) could not be used as an ANOVA effect size estimator instead of $\eta^2$ / $\eta p^2$, which are considered to be slightly biased measures and not recommended as measures of effect size (Skidmore & Thompson, 2013; Field, 2013)). Accuracy in the ambiguous word task was analyzed in the same way as reaction times, i.e., in a 2 x 2 repeated measures ANOVA and with the same variables and measures. To investigate any correlations between the stop signal reaction time and the difference between the incongruent ambiguous condition and the incongruent unambiguous condition in the ambiguous word task, and thus to explore $\boldsymbol{H_2}$, a Pearson product-moment correlation coefficient was computed for both SOAs. The same procedure was followed to assess the relationship between stop signal reaction time in the stop signal task and the reaction time in the incongruent ambiguous condition. To exclude any confounding variables due to lists, t-tests were also performed across all four lists. Frequency and correlation analyses were also performed for the ambiguous word task to investigate any significant exploratory results with regard to information obtained through the questionnaire.

# 3 Results

Of the original 45 participants, 35 (77%) returned the completed questionnaire. Questionnaires that belonged to participants who demonstrated accuracy <70% on the ambiguous word task were automatically excluded. After all results with RT <100 ms had been removed, along with participants with an overall accuracy <70%, the ambiguous word task showed a mean accuracy of .89. T-tests were performed across lists (1-4), conditions (1-4), and SOAs (250 vs. 750 ms), for both correct and incorrect trials, to exclude any confounding variables due to list. This led to the following: 1) Significant differences in accuracy in 5 sentences/combinations for list 1 vs. 2, 4 vs. 1, 1 vs. 3, and 2 vs. 4, with list 1 involved in 4 out of 5 instances. 2) The most apparent significance was found in the incongruent ambiguous condition (assumed to be the most challenging trial type), constituting 4 of the 5 instances of significance and having the highest overall significance ($p_{\text{mean}} = .02$). 3) A total of 144 comparisons resulted in 5 significant differences, constituting 3.5 %. However, this measure of significance is only relevant if all comparisons were independent of each other. 4) Taking 3) into account, along with the fact that the t-tests included all trials (also incorrect) to obtain an overall picture, led to the decision to aggregate over lists.

As to distribution of the data concerning accuracy and gender, a Shapiro-Wilk test showed $p = .017$ for females and 0.526 for males. A skewness of -1.130 (*SE* = 0.456) and a kurtosis of 0.996 (*SE* = 0.887) for the female participants and a skewness of -.354 (*SE* = .597) and a kurtosis of -.434 (*SE* = 1.154) for the male participants was observed, resulting in a skewness z-value of -2,478 and -0.593 for females and males, respectively, and a kurtosis z-value of 1.123 and -0.376, revealing that the data are a little skewed (left), especially for females, and to some extend kurtotic, as expected. Females (*N* = 26) had a slightly higher accuracy than males, with .91 (*SD* = .05) vs. .87 (*SD* = .05). This gave us a mean accuracy = .89 for all participants across genders (SD = .05). An overall Shapiro-Wilk test (across gender) on accuracy resulted in $p = .019$. A visual inspection of the normal Q-Q Plots and box plots showed that the accuracy was approximately normally distributed across gender. Figure 5 is a Quantile-Quantile plot of mean accuracy in the ambiguous word task across genders (*N* = 40).

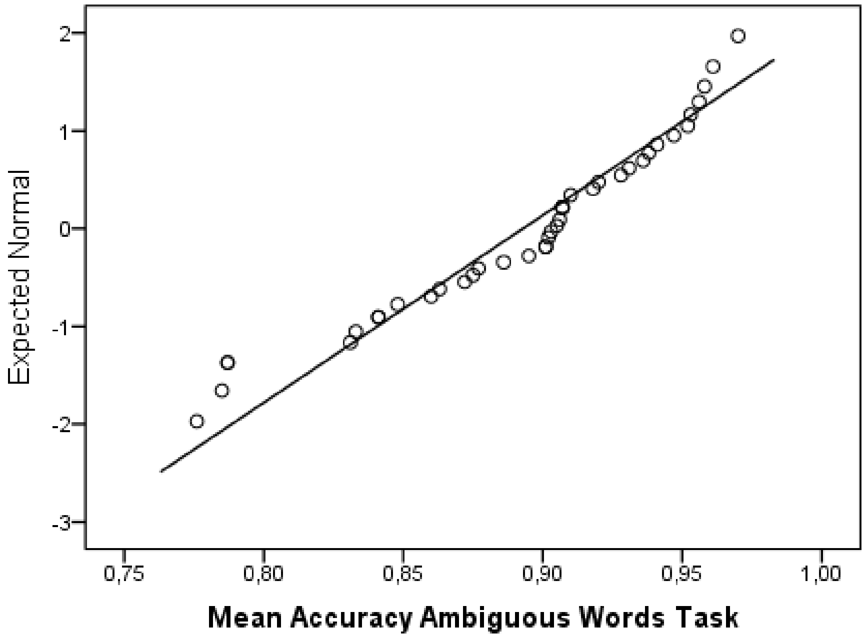

*Figure 5*. Q-Q plot of mean accuracy in ambiguous word task across genders.

As to sample characteristics regarding reaction times for all participants across conditions for SOA 250 ms, a skewness of 1.024 (*SE* = .374) and a kurtosis of .959 (*SE* = .733) could be observed. The same conditions for SOA 750 ms resulted in a skewness of .537 (*SE* = .374) and a kurtosis of .119 (*SE* = .733). When collapsing mean reaction times across conditions (1 to 4) and SOAs (250 and 750 ms), normal Q-Q plots and histograms showed slightly right-skewed results that were approximately normally distributed.

In the stop signal task, a skewness of .466 (*SE* = .456) and a kurtosis of -.769 (*SE* = .887) was observed for females. For males, the values equaled .521 (*SE* = .597) and 2.471 (*SE* = 1.154) for skewness and kurtosis respectively. Mean stop signal reaction times were 246.71 ms (*SD* = 30.51) for females, and 247.76 ms (*SD* = 33.07) for males. A Shapiro Wilk test showed no significance in either sex ($p_{\text{female}}$ =.231, $p_{\text{male}}$ = .374). Overall, the results from the SSRT in the SST (*N* = 40) showed a skewness of .469 (*SE* = .374) and a kurtosis of .204 (*SE* = .733). Both z-values were within the range of +/-1.96 (1.254 and 0.278 respectively); a Shapiro Wilk test showed no significance, with *p* = .764 (*SD* = 31.00). Visual inspections of the normal Q-Q Plots showed that the data were approximately normally distributed.

## 3.1 Results Hypothesis 1

To answer hypothesis 1, we first measured the difference in reaction time (RT) between the two incongruent conditions for each SOA: $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_250}$ and $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_750}$. T-tests showed no significant difference for SOA 250 ms. For SOA 750 ms, however, the difference was significant. The incongruent unambiguous condition had shorter reaction time than the incongruent ambiguous condition, as expected. In general (exploratory results), the incongruent ambiguous condition showed the longest reaction times of the four conditions, for both SOAs.

Table 3

*Mean Reaction Times measured in Milliseconds in the Four Different Conditions and SOAs in the Ambiguous Word Task*

| SOA | Mean RT (standard error) | | | |
|---|---|---|---|---|
| | Cong. ambig. | Incong. unambig. | Incong. ambig. | Cong. unambig. |
| 250 | 710 (31.77) | 734 (25.54) | 750 (22.57) | 711 (29.27) |
| 750 | 750 (22.23)* | 730 (21.33)* | 761 (27.76) | 700 (24.27)* |

*Note.* RT = Reaction Time in milliseconds; standard error of the mean in parentheses. SOA represents stimulus onset asynchrony in milliseconds; cong. = congruent; incong. = incongruent; ambig. = ambiguous; unambig. = unambiguous. * = significant difference from the incongruent ambiguous condition.

The difference between the incongruent ambiguous condition and the incongruent unambiguous condition was 16 ms for SOA 250 ms, and 31 ms for SOA 750 ms. With $p$ = .364, $t(39) = .92$, $d = 0.15$, a paired samples t-test showed no significant differences between the incongruent ambiguous condition and the incongruent unambiguous condition for SOA 250 ms, as mentioned above. However, for SOA 750 ms, the difference was significant, $p$ = .048, $t(39) = 2.05$; Cohen's effect size value showed a small to moderate effect with $d = 0.32$. As to the difference between the incongruent ambiguous condition and the congruent unambiguous condition for SOA 750 ms, the t-test had a significance level less than .001, $t(39) = 3.80$, $d = 0.60$. This was as expected, as answering Yes always involves less effort than answering No. The difference between the incongruent ambiguous condition and the congruent ambiguous condition was also significant, with $p = .022$, $t(39) = 2.39$, $d = 0.38$. This was in line with our expectations.

To evaluate the main effects of the incongruent unambiguous condition and the incongruent ambiguous condition and SOAs on RT (exploratory results), a two-way repeated measures ANOVA was conducted. As expected, there was a significant main effect of condition on the RT, $F(1, 39) = 5.709$, $p = .022$, $\eta p^2 = .128$ However, for SOA, no significant main effect could be observed, $F(1, 39) = 0.074$, $p = .787$, $\eta p^2 = .002$. There was no significant interaction effect between condition and SOA, $F(1, 39) = .330$, $p = .569$, $\eta p^2 = .008$. Figure 6 represents the effect of stimulus onset asynchrony on reaction time.

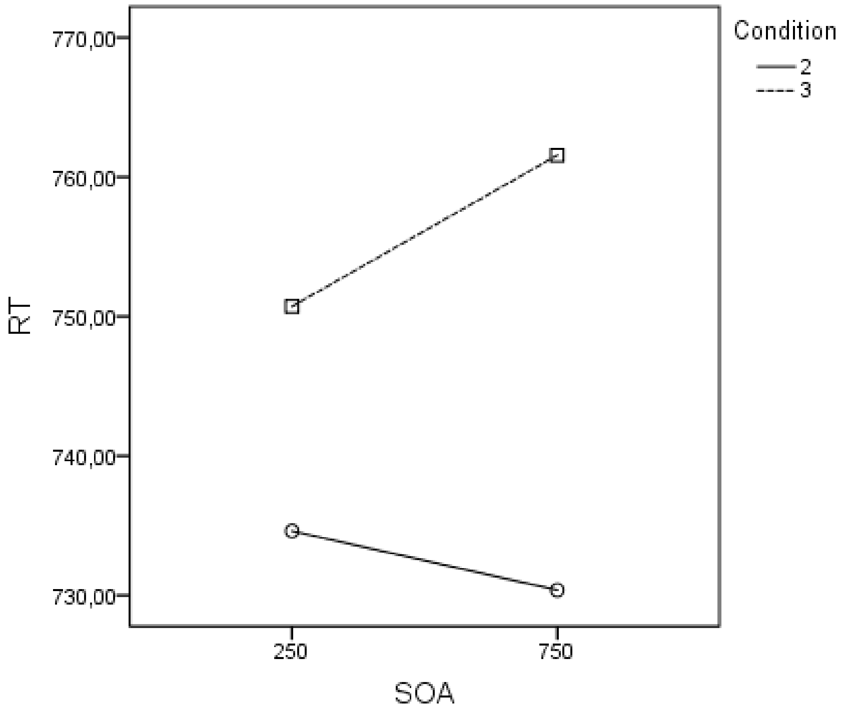

*Figure 6*. Effect of stimulus onset asynchrony on reaction time.
RT = reaction time, condition 2 = incongruent, unambiguous, condition 3 = incongruent, ambiguous, SOA = stimulus onset asynchrony 250 ms and 750 ms.

Mean accuracy in the ambiguous word task is presented in table 4.

Table 4

*Mean Accuracy in the Four Different Conditions and SOAs in the Ambiguous Word Task*

| SOA | Mean ACC (SD) | | | |
|---|---|---|---|---|
| | Cong. ambig. | Incong. unambig. | Incong. ambig. | Cong. unambig. |
| 250 | .84 (.13) | .93 (.78) | .91 (.90) | .89 (.12) |
| 750 | .82 (.14) | .94 (.84) | .95 (.11) | .89 (.13) |

*Note.* ACC = Accuracy, SD = Standard Deviation. Accuracy in the four different conditions, standard deviation in parentheses. SOA represents stimulus onset asynchrony in milliseconds. cong. = congruent; incong. = incongruent; ambig. = ambiguous; unambig. = unambiguous.

Paired t-tests showed no significant difference between SOA 250 ms and SOA 750 ms in the incongruent unambiguous condition, with $p = .356$, $t(39) = -.933$, nor was there any significant difference for the same independent variables in the incongruent ambiguous condition, with $p = .132$, $t(39) = -1.538$.

Contrary to expectations, the participants showed slightly higher accuracy in the incongruent ambiguous condition compared to the incongruent unambiguous condition for SOA 750 ms. As expected, the accuracy was higher in the incongruent ambiguous condition for SOA 750 ms than for SOA 250 ms.

We also wanted to evaluate the effect of condition and stimulus onset asynchrony on accuracy (ACC). To do so, a two way repeated measures ANOVA was computed. There was no significant main effect of condition on ACC, $F(1, 39) = .108$, $p = .744$, $\eta p^2 = .003$. SOA did not show any significant main effect either, with $F(1, 39) = 3.296$, $p = .077$, $\eta p^2 = .078$. As to interaction effects between condition and SOA on ACC, no significant results could be observed, $F(1, 39) = .532$, $p = .470$, $\eta p^2 = .013$.

Figure 7 shows the effect of stimulus onset asynchrony on accuracy.

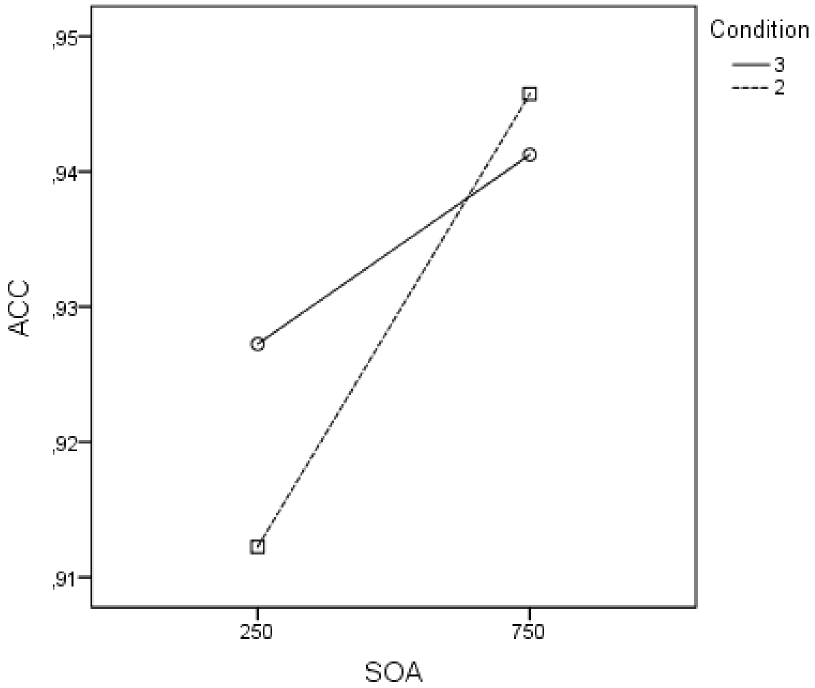

*Figure 7*. Effect of stimulus onset asynchrony on accuracy.
ACC = accuracy, condition 2 = incongruent, unambiguous, condition 3 = incongruent, ambiguous, SOA = stimulus onset asynchrony 250 ms and 750 ms.

Analyses were conducted to investigate any significant exploratory results related to the questionnaire. In this context, correlation studies were performed with regard to subjectively experienced tendency to confuse words, with overall accuracy in the ambiguous word task. A Pearson product-moment correlation coefficient was computed ($N = 29$). No significant correlation could be observed, mean accuracy ambiguous word ($M_{\mathrm{AmbigWord}}$) = .90 ($SD$ = .049), $r = -.041$, $p = .833$. As stress is also a typical factor linked to the ability to suppress irrelevant information, a correlation was computed for overall accuracy in the ambiguous word task versus subjectively perceived general stress level, $r = -.058$, $p = .766$; more specifically, reported low stress levels were not correlated with higher accuracy rates.

Finally, as to handedness ($N = 40$), left-handed individuals ($N = 5$) and right-handed individuals showed an almost equal overall accuracy, with $M_{\mathrm{LeftHand}} = 0.88$ ($SD = 0.06$) and $M_{\mathrm{RightHand}} = 0.89$ ($SD = 0.05$). Due to the unequal sample size, further measures were not taken. As to languages, half of the participants reported that they actively used two languages during an average week, 11% reported three languages. Approximately 90% reported being students or having a university degree. Given the statistical power with only 29 of the original 45 participants, we did not investigate the results from the questionnaire further combined with the two tasks.

## 3.2 Results Hypothesis 2

To assess the relationship between stop signal reaction time in the stop signal task and the reaction time in the incongruent ambiguous condition in the ambiguous word task (exploratory data), a Pearson product-moment correlation coefficient was computed for both SOAs. No significant correlation was found, for SOA 250 ms, $M_{\text{AmbigWord}} = 750.72$ ($SD = 142.72$), Pearsons's $r = .194$, $p = .231$, or for SOA 750 ms, Pearsons's $r = .073$, $p = .65$. See scatterplots summarizing the results in figures 8a and 8b.

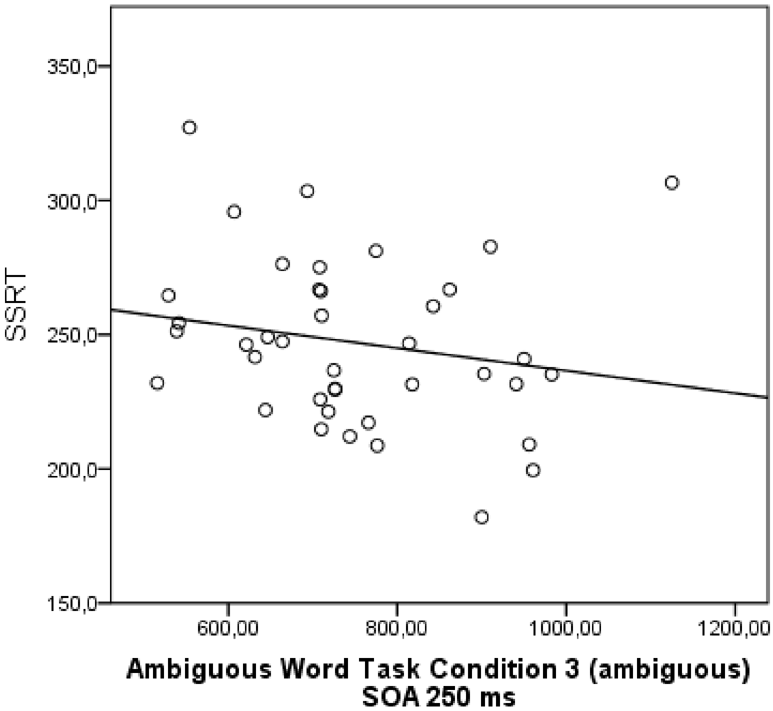

*Figure 8a.* Relationship between stop signal reaction time in the stop signal task and reaction time in the incongruent ambiguous condition in the ambiguous word task (condition 3). Stimulus onset asynchrony (SOA) = 250 ms.

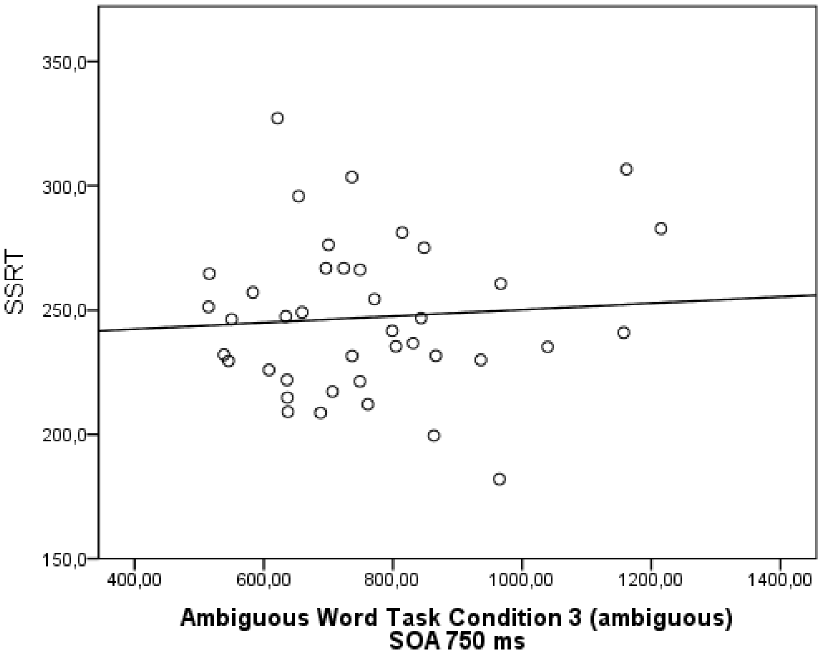

*Figure 8b*. Relationship between stop signal reaction time in the stop signal task and reaction time in the incongruent ambiguous condition in the ambiguous word task (condition 3). Stimulus onset asynchrony (SOA) = 250 ms.

To obtain more exploratory data, we also analyzed the relationship between the stop signal reaction time in the stop signal task (*M* =247.08, *SD* = 31.01) and the difference between the reaction times in the incongruent ambiguous condition and the incongruent unambiguous condition for SOA 250 ms (*M* = 16,11, *SD* = 111.07), and there was no significant correlation, with *p* = .278 and a negative *r* = -.176, as illustrated in figure 9a.

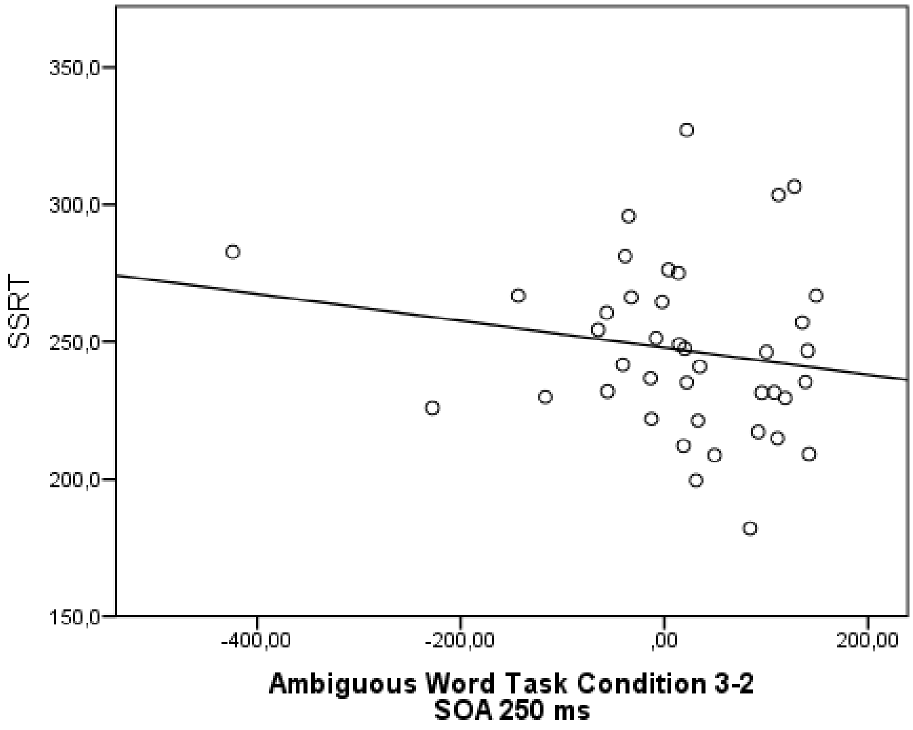

*Figure 9a.* Relationship between stop signal reaction time in the stop signal task and ($RT_{ambiguous}$ – $RT_{unambiguous})_{incongruent\_250}$ in the ambiguous word task. Condition 3 = incongruent ambiguous, condition 2 = incongruent unambiguous.

Analyses of the relationship between the stop signal reaction time in the stop signal task (*M* =247.08, *SD* = 31.01) and the difference between the reaction times in the incongruent ambiguous condition and the incongruent unambiguous condition for SOA 750 ms (*M* = 31.2, *SD* = 96.50) also showed no significant correlation, with *p* = .732 and a negative *r* = -.056, as illustrated in figure 9b.

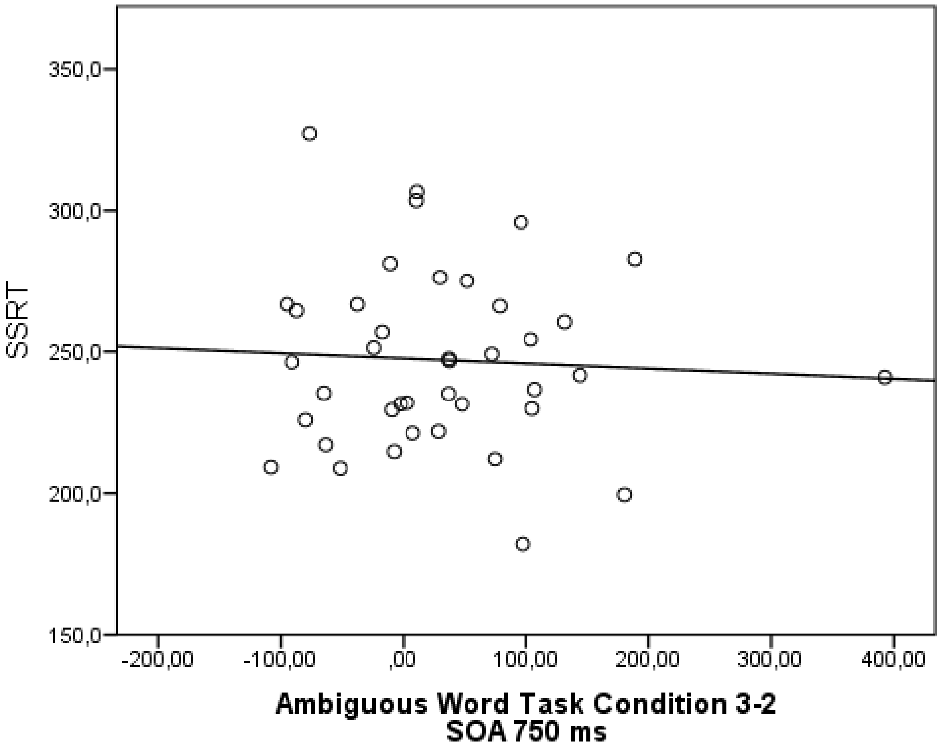

*Figure 9b*. Relationship between stop signal reaction time in the stop signal task and $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_750}$ in the ambiguous word task. Condition 3 = incongruent ambiguous, condition 2 = incongruent unambiguous.

As to the main analyses regarding ***H2***, correlation analyses of the stop signal reaction time in the stop signal task with the results from the ambiguous word task were performed using the following formula for the latter: $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_250} - (RT_{ambiguous} - RT_{unambiguous})_{incongruent\_750}$. The results showed $r = -.085$, $p = .603$ and thus no significant correlation, as illustrated in figure 10.

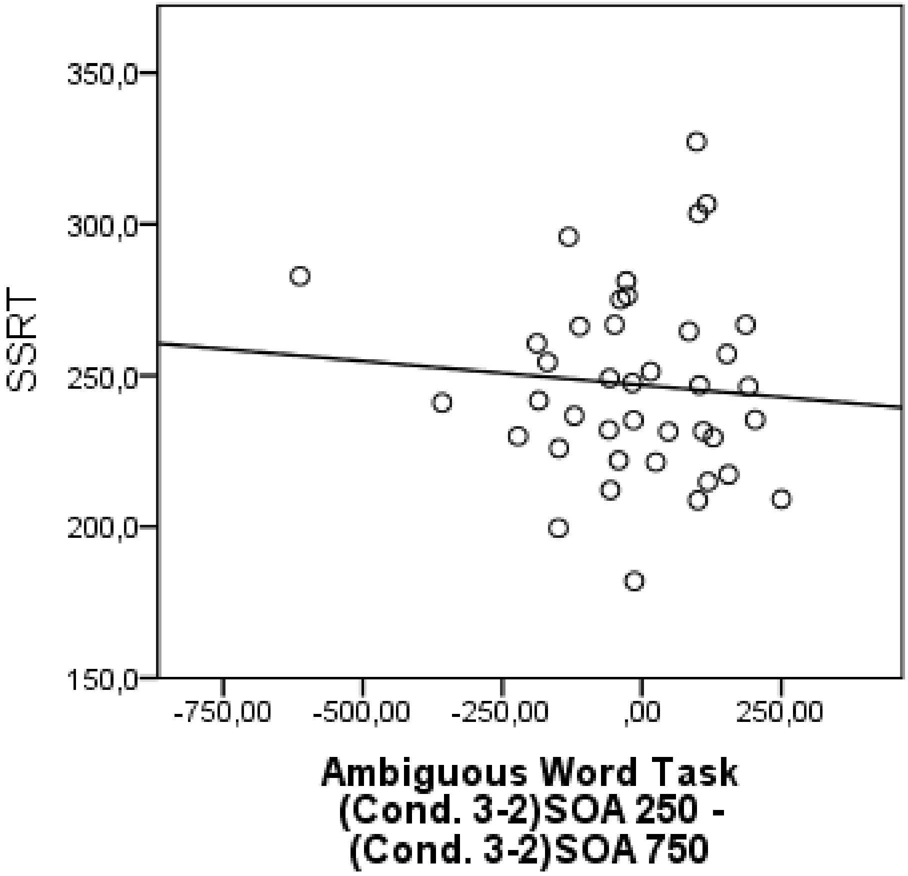

*Figure 10*. Relationship between stop signal reaction time in the stop signal task and the reaction time in the ambiguous word task with the main formula: $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_250} - (RT_{ambiguous} - RT_{unambiguous})_{incongruent\_750}$. Cond. 3 = incongruent ambiguous, cond. 2 = incongruent unambiguous.

With $r = .010$ and $p = .95$, no significant correlations could be identified between SSRT ($M = 247.08$, $SD = 31.00$), and reaction times in the ambiguous word task ($M = 726.28$, $SD = 143.82$) when computing correlations across all conditions and SOAs in the ambiguous word task.

To explore any correlations between mean *reaction time* in the stop signal task, e.g., mean reaction time on no-signal trials, that is, when the participants are supposed to answer ($M = 594.22$, $SD = 140.67$), and mean reaction time across all conditions and both SOAs in the ambiguous word task (mean and standard deviations above), correlation analyses were performed showing $r = .142$ and $p = .382$ and thus no significant correlations.

# 4 Discussion

The aim of the present study was to shed further light on semantic inhibition as a potentially separate kind of inhibition, and investigate if there is a correlation between semantic inhibition and behavioral (motoric) inhibition. In doing so, we applied a novel ambiguous word task and a classic stop signal task. To our knowledge, a Norwegian equivalent of the task in Experiment 4 in Gernsbacher, Varner, and Faust (1990) does not exist. Using that task as a partial basis, we constructed a new task that lets us control for sentence and word length, accommodate differences in how long it takes to understand the sentences, and isolate the relationship between probe and target. We also adjusted the delay parameters.

## 4.1 Discussion Hypothesis 1

$H_1$ only covered the ambiguous word task. We hypothesized that answering on semantic-related tasks involving homonyms requires a high degree of cognitive effort. Given this, subjects' inhibition abilities in this context should be mirrored by significant differences in reaction times (RTs) and accuracy based on conditions, more specifically an incongruent condition with unambiguous words and an incongruent condition with ambiguous words, and on stimulus onset asynchronies (SOAs). If this alternative hypothesis could be supported, subjects should also have longer reaction times when answering correctly on tasks with ambiguous words than when answering correctly on tasks with unambiguous words.

Our measure for semantic inhibition based on reaction time for $H_1$ was obtained by $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_SOA}$. The difference for SOA 250 ms did not support the hypothesis. For SOA 750 ms, however, the hypothesis was supported. The difference between the incongruent ambiguous condition and the congruent unambiguous condition for SOA 750 ms was significant. The difference between the incongruent ambiguous condition and the congruent ambiguous condition was also significant. This was in line with our expectations. In sum, as expected, the incongruent ambiguous condition showed the longest reaction times of the four conditions, in both SOAs. This longest RT was observed in SOA 750 ms. Longer SOAs potentially increase uncertainty and thus require inhibitory processes. This could also be explained by system 1 and system 2 thinking, with system 1 as the automatic, effortless, and quick thinking with no voluntary control, and system 2, associated with complex, effortful, and rational thinking (Kahneman, 2011).

More specifically, the incongruent unambiguous condition had shorter reaction time than the incongruent ambiguous condition, as hypothesized.

When evaluating the main effects of the incongruent ambiguous conditions and the incongruent unambiguous condition and both SOAs on RT, a significant main effect of condition on RT was observed, as expected. When it comes to SOA, however, no significant main effect could be observed. Moreover, there was no significant interaction effect between condition and SOA. Further, the analyses showed no significant difference between SOA 250 ms and SOA 750 ms in the incongruent unambiguous condition. There was also no significant difference while observing the same independent variables in the incongruent ambiguous condition.

Contrary to expectations, the participants showed slightly higher accuracy in the incongruent ambiguous condition compared to the incongruent unambiguous condition for SOA 750 ms. According to expectations, the accuracy was higher in the incongruent ambiguous condition with SOA 750 ms than with SOA 250 ms. For SOA 750 ms, the mechanism of suppression has potentially reached a threshold where it is more activated.

We also evaluated the effect of condition and stimulus onset asynchrony on accuracy, and found no significant main effect of condition in this respect. Neither did SOA show any significant main effect on accuracy. No interaction effects between condition and SOA on ACC could be observed. To explore any significant results related to the questionnaire, correlation studies were performed with regard to subjectively experienced tendency to confuse words, with overall accuracy in the ambiguous word task. No significant correlation could be observed. As stress is also a typical factor linked to the ability to suppress irrelevant information, the correlation between overall accuracy in the ambiguous word task and subjectively perceived stress level was computed; however, self-reported low stress levels were not correlated with higher accuracy rates. Finally, as to handedness ($N = 40$), left-handed individuals ($N = 5$) and right-handed individuals showed an almost equal overall accuracy in the ambiguous word task. Due to the unequal sample size, further measures were not taken. Given the statistical power with only 29 of the originally 45 participants, it was decided not to investigate the results from the questionnaire further.

Although females had a slightly higher accuracy than males in the ambiguous word task, t-tests showed no significant differences between the two genders.

In sum, $\boldsymbol{H_1}$ was partially supported, as our measure for semantic inhibition based on reaction time was obtained by $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_SOA}$ and t-tests showed no significant difference for SOA 250 ms, but a significant difference for SOA 750 ms.

## 4.2 Discussion Hypothesis 2

Based on existing literature about various forms of inhibition, we stated in $\boldsymbol{H_2}$ that inhibition on a higher (semantic) level and inhibition on a lower (motoric) level are two distinct forms of inhibition mechanism. Here, the novel ambiguous word test represented the higher level, whereas a version of the well-known stop signal task represented the lower level. Moreover, if the hypothesis could be supported, there should also be no significant correlations between the *reaction times* in the stop signal task and the overall reaction across conditions and stimulus onset asynchronies in the ambiguous word task. The relationship between stop signal reaction time in the stop signal task and the reaction time in the incongruent ambiguous condition in the ambiguous word task was assessed with correlation analysis, and no significant correlation was found for either SOA. Analyses of the relationship between the stop signal reaction time in the stop signal task and the difference between the reaction times in the incongruent ambiguous condition and incongruent unambiguous condition showed no significant correlation for either SOA. Correlation analyses of the stop signal reaction time in the stop signal task with the results from the ambiguous word task with the formula $(RT_{ambiguous} - RT_{unambiguous})_{incongruent\_250} - (RT_{ambiguous} - RT_{unambiguous})_{incongruent\_750}$ showed no significant correlation. Correlation analyses of stop signal reaction time in the SST and the mean of all four conditions with correct answers for both SOAs (250 ms and 750 ms) in the ambiguous word task showed no significant correlations. After correlation analyses of mean reaction time in the stop signal task (i.e., mean reaction time on no-signal trials), and mean reaction time across all conditions and both SOAs in the ambiguous word task were performed, no significant correlations could be observed.

The failure to observe any significant differences or correlations, positive or negative, between the stop signal reaction time in the stop signal task and the reaction time in the ambiguous word task in any of the performed analysis combinations supports the idea that these depend on different forms of inhibition, and that these forms, while conceptually similar, are potentially not recruiting a single underlying mechanism, but to some degree have different neural correlates.

## 4.3 General Discussion

All human languages feature semantic and lexical ambiguity. Gernsbacher, Varner, and Faust (1990) took advantage of how linguistic phenomena like ambiguity can serve as a tool when investigating inhibitory processes involved in cognitive control, while paving the way for the present study. In their study, the authors compared how rapidly participants verified that a word was not related to a sentence when the last word was unambiguous, with how rapidly they verified that the same word was not related to the same sentence when the last word was replaced by an ambiguous word, where one of its meanings was used in the sentence, and the test word matched its other meaning. This comparison provided a measure of how activated the inappropriate meaning of the ambiguous word was and of the ability to suppress the inappropriate meaning.

In this study, we did not find any correlations between the ambiguous word task and the stop signal task, in line with our hypothesis and earlier studies that have identified different forms of inhibition. Our work supports the possibility that these different forms of inhibition have distinct neural correlates. As both tasks were measured by reaction times, and it is in general to be assumed that people who are fast responders would perform well in this respect on all kinds of inhibition tasks, the question still remains as to why no correlations could be observed. One potential answer could be that people develop strategies with different effects while performing tasks like the ones in this context.

The drift diffusion model (DDM) is a well-defined computational model of decision-making and a commonly used tool to infer latent psychological processes underlying decision-making in two-alternative forced choice tasks in terms of accuracy and reaction times and to link them to neural mechanisms based on response times (Wiecki, Sofer, & Frank, 2013; Smith, 2000). The model is considered optimal because it delivers a decision of specified accuracy in the shortest possible time (Bogacz, Brown, Moehlis, Holmes, & Cohen, 2006). It is also described as a continuum limit of the random walk model (Bogacz et al., 2006). The models' underlying assumption is that the brain extracts a constant piece of evidence per time unit from the stimulus (drift) which is disturbed by noise (diffusion), and that it accumulates this evidence over time (Bitzer, Park, Blankenburg, & Kiebel, 2014). Once the brain has sampled enough evidence and a decision is made, this accumulation stops (Bitzer et al., 2014). The models have been used to quantitatively analyze behavioral data such as accuracy and reaction times (Ratcliff, 1978; Ratcliff & McKoon, 2008) and reaction time distributions in a wide range of categorization and memory retrieval tasks (Bitzer et al., 2014), and to describe neurophysiological data qualitatively (Bitzer et al., 2014). Figure 11 gives a detailed overview of the model.

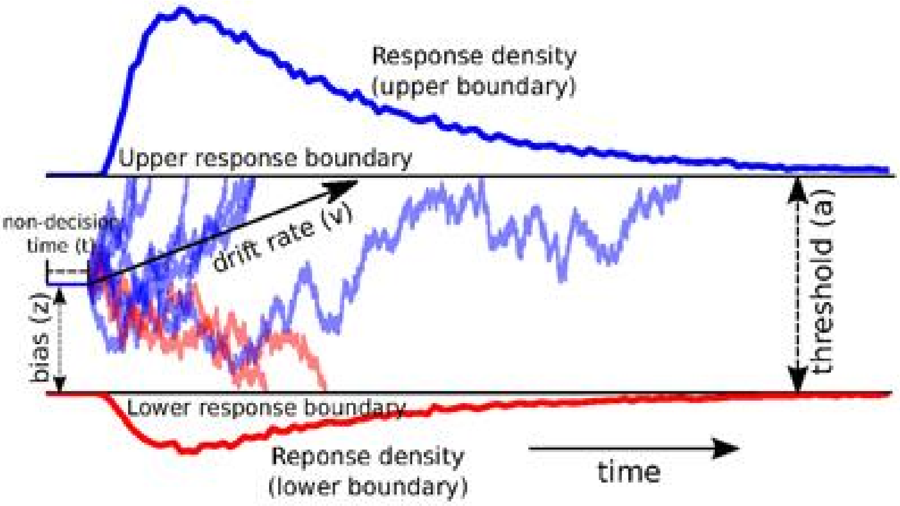

*Figure 11*. Drift diffusion model.
Multiple drift-processes, blue and red lines, middle panel as trajectories. Evidence is noisily accumulated over time (abscissa) with average drift-rate v until one of two boundaries (separated by threshold a) is crossed and a response is initiated. Upper (blue) and lower (red) panels show density plots over boundary-crossing times for two possible responses. Flat line in the beginning of the drift-processes: non-decision time (t) where no accumulation takes place. Illustration description with minor modifications and illustration courtesy, Wiecki, Sofer, and Frank, 2013.

The drift diffusion model is interesting in this context if we assume that the threshold for answering yes or no on a given task is lower if the task requires an input within the shortest range of time (in our case with the ambiguous word task, an SOA of 250 ms). Uncertainty would then reflect the impulse (or “push”) needed to overcome that threshold. Assuming an example where it takes 100 ms to be 70% certain with a short SOA, but 150 ms to be 80% certain with a long SOA implies that the threshold increases from 70 to 80 with a long SOA. In our case, we observed accuracies of .93 and .94 in the incongruent, unambiguous condition for SOA 250 ms and 750 ms, respectively. For the incongruent ambiguous condition, the results were .91 and .95 for SOA 250 ms and 750 ms, respectively. When it comes to reaction times in the incongruent unambiguous and the incongruent ambiguous condition, a shorter reaction time could only be observed for SOA 250 ms in the incongruent ambiguous condition, with RT 750 ms and 761 ms for SOA 250 ms and 750 ms, respectively. In our experiment, our main explanation is that participants experience insecurity when faced with the ambiguous probes that require them to inhibit irrelevant meanings. The time it takes for them to inhibit gives us an estimate of the difficulty of the task, and their ability to inhibit irrelevant context. An alternative explanation of the data could be that the insecurity they experience generates a need for more evidence before they give their responses. This phenomenon could be illustrated by the mentioned drift diffusion model. Both approaches leave us with the question about the information obtained by the difference between the SOAs of 250 ms and 750 ms regarding inhibition and insecurity in the context of ambiguous probes. The present study was not designed to investigate drift diffusion modeling further; however, it could be relevant for future studies within the field.

### 4.4 Strengths and limitations of the present study

This study applies the stop signal paradigm, which has been found useful in numerous research settings and in different task versions through decades, due to its valid and reliable measures. The solid empirical and theoretical foundation justifies the use of the paradigm in this study. The sentences were evaluated by an additional five persons before the implementation of the final version in the sentence list. Analyses of the sentence list with regard to word frequency, length of sentence, and length of word constitute another strength, together with analyses to uncover potential confounding variables due to significant differences between the various combinations of sentences and probe/target word. The sample is taken from various populations, however, the majority of the participants were students or reportedly had a higher degree. Thus, the results could potentially be influenced by higher cognitive skills and abilities, as they do not represent an average population or demographic distribution. On the one hand, the research setting is within a certain frame, quite similar to a lab testing. On the other hand, as the present study aims at shedding light on a specific paradigm given certain conditions, the test surroundings should not constitute any problem in our context.

In the ambiguous word task, trading off speed for accuracy and vice versa could not be controlled for, and therefore constitutes a limitation. The instruction “Be as accurate and fast as you can” may have seemed like a contradiction from a participant’s perspective (and truly is). Some participants indeed scored close up to 100% and had longer reaction times. This could potentially, but not necessarily, indicate an emphasis on accuracy, and it is a well-established fact that some subjects are more inclined than others to favor accuracy. As to the frequency analysis, analyses like the one presented mostly come along with some challenges, e.g., words implemented in the sentences were presented in the present or past tense, but had to be analyzed in the infinitive; some verbs are also used as nouns and vice versa, and in singular or plural. However, given the enterprise of finding adequate homonyms/words like the present ones, and how they affect the semantics and thus influence the other words in the context, the findings were regarded sufficient in all important respects to give us valid data with which to work. As all participants received the same sentences, and the lists were randomized and allocated randomly between the participants, there should not be any systematic effects.

In the stop signal task, trade-off was controlled for by means of the staircase method, meaning that the stop signal delay was adjusted trial-by-trial to keep the task difficulty constant. The stop signal reaction time in the stop signal task is a well-established paradigm and measure of inhibition ability. However, how inherent motivational biases (e.g., do SSRT estimates actually reflect cognitive processes that are impenetrable to external influence) (Leotti & Wager, 2010), explicit strategic control (Leotti & Wager, 2010), individual traits (Sella, Bonato, Cutini, & Umiltà, 2012) influence and bias the results, are increasingly subject to research. These factors should therefore be taken note of when conducting studies with the paradigm.

Due to the fact that the participants had to press “A” on the keyboard in order to respond “Yes” on any given task, and “A” is to the left on the keyboard, some of the right-handed participants reported they had to invest more cognitive effort, as they were more likely to use the right hand (reported as “the positive side”) whenever answering “Yes,” a finding we had not taken into account and that potentially may have caused confusion among some participants.

Measures to prevent biased results were also taken through the questionnaire. Stress, along with mental fatigue, may decrease the ability to suppress irrelevant information, resulting in a tendency to increasingly base response decisions on irrelevant information (Faber, Maurits, & Lorist, 2012). Varying the presentation order of the two tasks (SST and ambiguous word task) was not considered necessary, especially since changing the sequence would not constitute any guarantee of, e.g., fatigue being involved. A variable that could not be controlled for was the actual attentional effort, a cognitive incentive that integrates implicit and explicit motivational forces (Sarter, Gehring, & Kozak, 2006). More specifically, to which extent a subject was motivated to invest and/or increase attentional effort in order to maintain good performance during the experiment was not measured (and was not part of the questionnaire, given the high probability of people answering in accordance with perceived expectations about appearing as motivated as possible in voluntary experiments like the present one). Finally, there were, as in any study, limitations in the sense that only selected factors were examined; other samples and other preferences with regard to statistical analyses and modi operandi may result in other findings despite dealing with the same concept and tasks.

## 4.5 Implications for clinical work and future research

The present study on inhibition was performed with healthy participants with no symptoms of experienced trauma. Findings from studies on individuals with a history of trauma suggest that early trauma might adversely impact the development of brain circuits and cognitive systems that support inhibitory aspects of executive functioning (Marshall et al., 2016). In their study, Catarino, Küpper, Werner-Seidler, Dalgleish, and Anderson (2015) found that patients with the largest deficits in suppression-induced forgetting were those who experienced the most severe PTSD symptoms. The findings support the notion that prefrontal mechanisms supporting inhibitory control over memory are impaired in PTSD (Catarino et al., 2015). In another study with functional magnetic resonance imaging, Falconer et al. (2006) found that an increased inhibitory error and reduced right frontal cortical activation in participants with PTSD were consistent with compromised inhibitory control in PTSD. More specifically, during inhibition, control participants activated a right-lateralized cortical inhibitory network, whereas participants with PTSD only activated the left lateral frontal cortex, simultaneously showing an increased activation of striatal and somatosensory regions (Falconer et al., 2006), implying that PTSD could be the result of a deficient inhibitory system. Several studies have been conducted to gain a better understanding of personality and abnormal behavior (Gorfein & MacLeod, 2007). For example, Wood, Mathews, and Dalgleish (2001) found that subjects who were high in trait anxiety did not differ from subjects who were low in trait anxiety with respect to inhibition abilities in a task involving homographs; however, when the participants were subject to a higher cognitive load, the pattern changed, and subjects who were high in anxiety showed a general impairment in inhibitory processing (Wood, Mathews, & Dalgleish, 2001; Gorfein & MacLeod, 2007). Thus, it seems it takes specific conditions, such as a certain mental load, to “activate” limitation or impairment mechanisms of task-related control strategies. Inhibitory mechanisms have also been closely related to psychopathology; however, measures of putative inhibitory functions in psychopathology yield different result patterns (Gorfein & MacLeod, 2007).

All in all, this demonstrates that inhibitory mechanisms play a crucial role in everyday life, and that decreased inhibitory mechanisms probably account for a wide range of challenges. Gorfein and MacLeod (2007) remind us of the importance of continuous investigation of potentially distinct types of inhibition measures with different forms of psychopathology over the course of development. This includes both behavioral measures and experimental paradigms obtained from cognitive science (Gorfein & MacLeod, 2007). In this respect, the present study could serve as a foundation for future research on cognitive inhibition. Further, it could serve as a tool in experimental psychology when investigating cognitive processes in clinical conditions, e.g., trauma and psychopathology.

In this context, phenomena like the priming effect and the recency effect respectively expectations after a given sequence of stop/no-stop trials in the stop signal task and even also in the ambiguous word task should be addressed. For the case of reading, already quite early psychological studies (e.g., McClelland & Rumelhart, 1981) emphasized the fact that the knowledge of the objects we might be perceiving works together with the sensory information in the perceptual process (McClelland & Rumelhart, 1981). The question would then be how the knowledge we already have interacts with the input, and how this interaction facilitates perception (McClelland & Rumelhart, 1981). In their 1982 article “Variants of Uncertainty”, Daniel Kahneman and Amos Tversky discuss perceptual expectancies and present three main types of expectation, namely passive and active expectations, where the passive expectation can be permanent or temporary. An active expectation occupies consciousness and draws on the limited capacity of attention. In contrast, a passive expectation is effortless and automatic (Posner, 1978; Kahneman & Tversky, 1982). An observer can be prepared, or primed, for one event while consciously expecting another. Thus, individuals may have conflicting probabilities for the same event at the same time. Taken together, passive expectations and conscious anticipations can conflict, and there is evidence that the passive process exerts greater influence on the interpretation of ambiguous stimuli (Kahneman & Tversky, 1982). How these processes—within milliseconds—affect the potential activation of inhibition mechanisms in the case of ambiguous stimuli, and thus the responses given by individuals at any time, remains to be elucidated and could constitute a basis for further research.

In sum, the findings in the present study may be explained from a drift diffusion model perspective with insecurity as the main factor instead of inhibition mechanisms. In addition, alternative interpretations have been discussed. The strength of the conclusions is potentially confined by the limitations. In future studies, a higher statistical power could be obtained by recruiting more participants and draw on other variables, e.g., a more comprehensive questionnaire, to investigate more variables in the context of inhibition mechanisms.

# 5 Conclusion

In conclusion, the present study presented two hypotheses, where ***$H_1$*** with predictions was partially supported, stating that semantic-related tasks where homonyms are involved require a high degree of cognitive effort; hence, subjects' inhibition abilities in this context were mirrored by significant differences in reaction times and accuracy. As to ***$H_2$***, stating that there is no significant correlation between inhibition on a semantic and a behavioral level, the hypothesis could be supported as no significant correlations could be observed. The study may serve as a tool for future research on inhibition in clinical conditions.

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# APPENDICES

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| **Appendix I:** | **Sentence List** |
| **Appendix II:** | **Pilot Study** |
| **Appendix III:** | **Questionnaire** |