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The Influence of Distractors in Picture Naming:
A Quantitative Meta-Analysis

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ZUSAMMENFASSUNG

Seit Jahrzehnten untersucht die Forschung zur Wortproduktion, wie Wörter aus dem mentalen Lexikon abgerufen werden. Eine zentrale Frage ist dabei, ob semantisch verwandte Wörter während des lexikalischen Zugriffs miteinander konkurrieren und so zu einem semantischen Interferenzeffekt führen. Zwei theoretische Ansätze prägen diese Debatte. Die kompetitiven Modelle nehmen an, dass mehrere bedeutungsähnliche Wörter gleichzeitig aktiviert werden und um die Auswahl konkurrieren, welches zu verlangsamten Reaktionszeiten führt. Die nicht-kompetitive Modelle, insbesondere die „Response Exclusion Hypothesis", lehnen diese Sicht ab. Sie argumentieren, dass das Zielwort unabhängig von anderen aktivierten Wörtern ausgewählt wird und mögliche Interferenzen erst in späteren Phasen, etwa während der Artikulation, entstehen. Zudem wird angenommen, dass gleichzeitig aktivierte Wörter die Verarbeitung sogar erleichtern können.

Eine gängige Methode zur Untersuchung dieser Prozesse ist das Bild-Wort Interferenz Paradigma. TeilnehmerInnen benennen ein Bild, zum Beispiel Löwe, und ignorieren dabei ein Ablenkerwort, welches entweder semantisch verwandt (Zebra) oder unverwandt (Buch) ist. Einige Studien finden Interferenz, andere Erleichterung, obwohl ähnliche Methoden verwendet wurden. Auch wurde untersucht, ob nicht-sprachliche Ablenker, wie Geräusche oder Bilder vergleichbare Effekte auslösen. Die kompetitiven Modelle werten Interferenz als Beleg für lexikalischen Wettbewerb, während die „Response Exclusion Hypothesis" annimmt, dass nur Wörter über einen Antwortpuffer stören und es deshalb zur Interferenz kommt. Weiters nehmen sie an, dass nichtsprachliche Reize unter anderen Mechanismen verarbeitet werden.

Im Rahmen dieser Masterarbeit wurde eine Meta-Analyse durchgeführt, um zu untersuchen, ob der semantische Interferenzeffekt von der Art des Ablenkers abhängt. Konkret wurde untersucht, ob semantisch verwandte nichtsprachliche Ablenker ebenfalls semantische Interferenz auslösen können oder ob dieser Effekt ausschließlich durch Wort-Ablenker hervorgerufen wird. Zusätzlich wurde geprüft ob semantischer Erleichterungseffekt beobachtbar ist. Die Ergebnisse zeigen, dass Wort-Ablenker signifikante Interferenzeffekte hervorrufen, Geräusche und Bilder aber nicht. Auch ein Erleichterungseffekt wurde nicht gefunden. Obwohl die Befunde mit beiden Modellen vereinbar sind, wird keines vollständig gestützt. Bisher hat keine Studie alle drei Ablenkerarten direkt miteinander verglichen. Der fehlende Effekt bei Geräusch und Bild könnte mit der geringen Anzahl verfügbarer Studien in diesem Bereich zusammenhängen. Die Ergebnisse leisten dennoch einen Beitrag zur theoretischen Debatte und unterstreichen den Bedarf an weiterer Forschung zu nichtsprachlichen Ablenker.

ABSTRACT

For decades, research in word production has examined how words are retrieved from the mental lexicon. A central issue is whether semantically related words compete during lexical access, causing semantic interference. Two major theoretical accounts frame this ongoing debate. Competitive models assume that multiple related words are activated simultaneously and compete for selection, with the most strongly activated word ultimately being selected. This competition slows down the selection process, resulting in longer response times, a phenomenon known as semantic interference. In contrast, non-competitive models, particularly the Response Exclusion Hypothesis, reject this view. They argue that the target word is selected independently of other activated items and that interference might arise only during articulation. Moreover, they suggest that co-activated words may even facilitate processing, resulting in semantic facilitation.

A common method to investigate these processes is the picture-word interference task, in which participants name a picture, for example *lion*, while ignoring a distractor word that is either semantically related, *zebra*, or unrelated, *book*. Some studies find interference, others facilitation despite using similar methods. Researchers have also asked whether non-verbal distractors such as sounds and pictures produce similar effects. Competitive models interpret any interference as support for lexical competition. In contrast, the Response Exclusion Hypothesis claims that only word distractors interfere via a response buffer, while non-verbal stimuli involve different non-lexical mechanisms.

This thesis presents a meta-analysis examining whether semantic interference depends on different types of distractors. Specifically, whether semantically related non-verbal distractors can elicit semantic interference or whether this effect is exclusive to word distractors. It also investigated whether semantic facilitation occurred. The results showed that only word distractors produced significant interference effects; sounds and pictures did not. No facilitation effect was observed. While some aspects of the findings align with both models, neither account is fully supported. To date, no study has directly compared all three distractor types. The absence of effects for non-verbal distractors might reflect the limited number of available studies using sounds and pictures. Nevertheless, the findings therefore contribute to the ongoing debate and highlight the need for further research on non-lexical distractors.

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1. INTRODUCTION

For humans, speaking and using words to form meaningful and comprehensible sentences is taken for granted. But how is that humans are usually able to retrieve exactly the word they intend to say during communication? What cognitive processes ensure that intended word is selected and not a related alternative word? While contextual cues play a crucial role in lexical selection, occasional speech errors, such as saying *apple* instead of *pear*, suggest that word retrieval is not entirely predictable. These errors raise fundamental questions about how words are accessed and selected in the mental lexicon. The mental lexicon can be thought as a mental dictionary where all the information about each words an individual knows are stored, including their meanings, pronunciations and grammatical properties (Levelt, 1989). In the field of word production, one of the central questions is how this selection process works. A prominent theoretical account proposes that lexical access involves a competitive selection process (Levelt et al., 1999). According to this view, multiple semantically or phonological related words are activated in parallel and only one is ultimately selected for articulation (Schriefers et al., 1990; Roelofs, 1992; Levelt et al., 1999). This view supports competitive lexical access models and provides an explanation for the semantic interference effect (Schriefers et al., 1990). This effect occurs when multiple semantically or phonologically similar words are activated simultaneously and compete for selection, which results in longer response latencies (Levelt et al., 1999). Competitive lexical access models interpret the semantic interference effect as evidence for lexical competition (Mahon et al., 2007; Spalek et al., 2013). Unlike competition in sports or economics, mental competition is not directly observable and is assumed to be driven by internal cognitive processes that are still not fully understood (Levelt et al., 1999). The concept of lexical competition can be illustrated by the word game *Activity*. In this game, one player draws a card with a specific target word, for example vacation, and must describe it without saying the word itself. The other players try to guess the target word by spontaneously calling out various related alternatives such as travel, beach, hotel, relaxation or summer, but not yet the target word until eventually someone says the correct word. These associations reflect the simultaneous activation of related lexical items in the mental lexicon as assumed by proponents of competitive models (Levelt 1989, Levelt et al., 1999). The challenge lies in identifying the correct word among several related candidates. It reflects a common challenge in the word production, namely selecting the correct word while suppressing other meaning-related alternatives that are also activated in the mental lexicon. However, not all researchers agree that semantic interference reflects true competition between lexical access (Mahon et al., 2007). Non-competitive models, such as the Response Exclusion Hypothesis[1], argue that interference effects emerge only at later stages, particularly during articulation, while lexical selection itself proceeds without internal conflict (Dell, 1989; Mahon et al., 2007; Finkbeiner & Caramazza, 2006; Janssen et al., 2008). For this reason, this account is considered non-competitive with respect to lexical selection, since competition is assumed to occur after the lexical level during response preparation (Mahon et al., 2007, Janssen et al., 2008; Spalek et al., 2013). This theoretical

[1] Henceforth, the Response Exclusion Hypothesis will be abbreviated as REH

divide lies at the heart of ongoing debates in the field of lexical access (Spalek et al., 2013). While the idea of competition in lexical access is not universally accepted among linguists (Dell, 1989, Mahon et al., 2007) competition is assumed to play a key role in how language is produced (Levelt et al., 1999). In fact, within psycholinguistics, some processes are as strongly associated with competition as the act of speaking itself (Banaruee et al., 2023). According to certain models of lexical access, words, meanings and structures compete for selection during speech planning (Schriefers et al., 1990; Roelofs, 1992; Levelt et al., 1999). Spoken language requires a complex interplay of more than one process that transform abstract ideas into articulated speech (Finkbeiner & Caramazza, 2006a; Damian & Spalek, 2014). When speakers communicate, they know what they want to say and they need to know how the words are pronounced (Vromans & Jongman, 2018). A crucial component of this process is the retrieval of words from the mental lexicon (Levelt, 1989). It contains tens of thousands of items and in fluent speech speakers retrieve two or three words per second (Levelt et al., 1999). For this reason, speakers can use the information linked to a word to generate new sentences they have never produced before (Levelt, 1989). Therefore, process of lexical access is fundamental to fluent speech. When speakers articulate, they retrieve the appropriate words from the mental lexicon rapidly and accurately, otherwise fluent speech would not be possible. For most speakers, effortlessly retrieving and articulating the words they intend to say seems natural, unless disrupted by a language or speech disorder. Yet this process is driven by a highly complex system. To illustrate the complexity of word production, Spalek et al. (2013) use the analogy of a 100-meter race, which is well-suited to describe the highly complex system of word production. In a 100-meter race, each runner has their own lane. As soon as the starting signal sounds, the competitors sprint forward, each staying in their marked lane. The goal is to reach the finish line as quickly as possible. The fastest runner wins. This competition mirrors what may happen during word retrieval in word production (Spalek et al., 2013). Once a concept is selected, multiple lexical candidates are activated in the mental lexicon, but only one word *wins* the competition resulting in articulation (Spalek et., 2013). This retrieval process involves several stages, including the activation of syntactic, phonological and semantic information associated with the intended word (Levelt, 1989; Schriefers et al., 1990; Dell & O'Seaghdha, 1992; Roelofs, 1992). Thus, the frequency of word usage, the semantic similarity to other words and the context as well the environment in which a word is being retrieved can all affect how quickly and accurately a word is accessed (Levelt, 1989; Schriefers et al., 1990; Mahon et al., 2007; Marsh et al., 2017).

One commonly observed effect that sheds light on the nature of lexical access is the semantic interference effect (Schriefers et al., 1990). The phenomenon is typically studied using picture naming tasks. Participants are shown a picture, for example bee, along with a distractor word that is either semantically related (fly) or unrelated (mountain). The competitive view argues that naming latencies are longer when the distractor is semantically related, indicating a semantic interference effect (Levelt et al., 1999). In contrast, the REH argue that a semantically related distractor facilitates the target word (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007). The semantic effect has been central to the debate on how lexical selection occurs and is a critical concept in the study of lexical access, particularly in the context of picture naming studies (Spalek et al., 2013). These types of studies have become a central method for understanding how words are retrieved from the mental lexicon, as they allow researchers to examine how the presence of semantically related distractors affects the speed and accuracy of word retrieval (Spalek et al. 2013). Over decades researchers have used Picture-Word Interference[2] tasks, a widely used method in psycholinguistics (Spalek et al., 2013). Although now widely used to study lexical access, PWI tasks were originally introduced to examine automatic semantic processing during reading in children (Rosinski et al. 1975). Around the 1990s, researchers began replacing PWI studies with other types of distractors, such as sounds or pictures, known as Picture-Sound Interference[3] or Picture-Picture Interference[4] paradigm, respectively (Schriefers et al., 1990; Cutting & Ferreira, 1999). At this point it is important to justify why picture stimuli can also be considered as potential distractors in picture naming tasks. Most models of speech production assume that lexical selection takes place before phonological encoding (Levelt et al., 1999). Although both pictures and words can function as distractors in experimental paradigms, they reach the lexical level via different routes but are nevertheless capable of producing similar effects (Jescheniak et al, 2020). While distractor words directly access the lexical level and immediately activate the corresponding lexical entry, distractor pictures first undergo conceptual processing (Roelofs, 1992; Jescheniak et al., 2020). Despite this difference, studies have shown that picture distractors can indeed activate lexical nodes and even cause phonological facilitation effects, especially when they share phonological similarity with the target (Navarrete & Costa, 2005). This indicates that pictures are also capable of participating in the competition for lexical selection, like distractor words (Geng et al., 2013). By manipulating the type of distractors researchers have been able to uncover the competitive nature of lexical access and the underlying processes that drive semantic interference (Spalek et al., 2013).

These mixed findings have contributed to a major theoretical divide in this field. As Mädebach et al. (2018: 1910) put it: "Disagreement exists about how a target word is selected among these concurrently activated representations". On the one hand, researchers who support competitive accounts interpret interference as a direct consequence of lexical competition (Schriefers et al., 1990; Levelt et al. 1999; Damian & Bowers, 2003; Damian & Spalek, 2014). On the other hand, proponents of the non-competitive models argue that interference may emerge independently of competition, for example due to speech errors (Dell, 1989) or interference is a result of the output buffer (Finkbeiner & Caramazza, 2006b, Mahon et al., 2007). However, most studies report a consist pattern in which a target picture semantically related to a distractor, whether it is a word, sound or a picture, interferes with the lexical retrieval process (Schriefers et al., 1990; Mädebach et al., 2017). The way these distractors affect naming speed reveals critical insights into whether word selection is a competitive or non-competitive process (Spalek et al., 2013). Accordingly, semantic interference has long been considered a key empirical argument in favour of a competition-based lexical selection mechanism (Mahon et al. 2007). The term *semantic interference* is often used as a substitute for the concept of lexical competition in the literature on language production (Mahon et al., 2007). Thus, the interpretation of the effect largely depends on the

[2] Henceforth, the Picture-Word Interference will be abbreviated as PWI.
[3] Abbreviated as PSI in the remainder of the thesis.
[4] Abbreviated as PPI in the remainder of the thesis.

theoretical framework applied (Mahon et al., 2007). Many classic naming studies, particularly those using the PWI paradigm, interpret interference effects as evidence that semantically related distractors compete with the target word at the lexical level (Levelt et al., 1999; Abdel Rahman & Melinger, 2009; Damian & Spalek, 2014). However, alternative explanations have been proposed, most notably the REH (Finkbeiner & Caramazza, 2006; Mahon et al., 2007; Janssen et al., 2008), which locates interference at the post-lexical stage, where the word is articulated. Remarkably, studies grounded in the competitive approach have failed to find interference effects (Damian & Bowers, 2003), despite this theoretical background. This underscores that semantic interference cannot be interpreted as direct evidence of lexical competition (Mahon et al., 2007). This has led to a decades-long ongoing debate about whether lexical access is competitive in nature (Spalek et al., 2013). Finkbeiner & Caramazza (2006a) emphasize that all lexical models share the common assumption that activation cascades from the conceptual level to the lexical level. They follow the principle "selection by activation" (Finkbeiner & Caramazza, 2006a: 1032) meaning that the item with the highest activation will be selected, regardless of the activation of other representations (Dell, 1986; Caramazza, 1997). But the core issue of the debate is at which level lexical access occurs, and which mechanisms are responsible for the interference effect and whether competition is involved. Some argue competition takes place at the lexical level (Schriefers et al, 1990; Levelt et al., 1999; Damian & Spalek 2014; Hutson & Damian, 2014; Mädebach et al., 2017, 2018); others suggest a post-lexical level (Finkbeiner & Caramazza, 2006; Mahon et al., 2007, Janssen et al., 2008, Dhooge & Hartsuiker, 2010, 2011; Marsh et al., 2017) and still others locate its origin at the conceptual level (Roelofs, 1992, Jescheniak et al., 2020), while non-competitive accounts such as Dell (1986) assume that lexical access occurs without competition, based on the threshold-crossing activation. In contrast, interactive models propose a distributed locus involving both lexical and phonological levels (Levelt, 1989; Dell & O'Seaghdha, 1992). As will be outlined throughout this thesis, some researchers have the view that only words can elicit a semantic interference effect as distractors, whereas other types such as sounds and pictures do not (Finkbeiner & Caramazza, 2006; Mahon et al., 2007, Janssen et al., 2008). However, more recent studies have challenged this perspective by using sounds or pictures as distractors alongside target picture and still observing semantic interference effects (Hanauer & Brooks, 2005; Navarrete & Costa, 2005; De Zubicaray & McMahon, 2009; Matushanskaya et al., 2016; Mädebach et al., 2017, 2018; Geng et al., 2013).

However, no previous study to date has systematically examined whether semantic interference effects vary as a function of distractor type. This thesis addresses that gap through a quantitative meta-analysis. The central aim is to determine whether semantic interference depends on the type of distractor and whether the effect is indeed restricted to word distractors as predicted by the REH or whether non-verbal distractors can produce comparable effects. Previous studies using words, sounds and pictures as distractors observed either interference or facilitation effects, depending on the experimental conditions (Sailor et al., 2009). Therefore, this meta-analysis includes studies reporting either outcome, including those in which semantically related distractors do not necessarily lead to slower responses compared to unrelated distractors (Damian & Bowers, 2003; Hanauer & Brooks, 2005).

Given these mixed findings this thesis main hypothesis is that the presence of a semantic interference effect depends on the type of the distractor. Specifically, interference is expected for word and sound, but not for picture distractors. This assumption is supported by the inclusion of only standard picture-word interference designs, as opposed to other variants such as masked priming or delayed naming. In line with the predictions of the REH, facilitation effects might arise when co-activated representations support processing. However, the present meta-analysis focuses exclusively on semantic interference effects by comparing semantically related and unrelated distractors. Facilitation effects are therefore not expected. It is not the aim of this thesis to determine whether lexical access is competitive in nature or at which level it occurs. However, these aspects will be discussed throughout the thesis alongside the results and previous findings.

The thesis is organized into the following chapters: The Introduction includes the theoretical background, which explores key models of word production, different approaches to lexical access, including the frameworks and the role of semantic interference in picture naming tasks.
The Methodology chapter details the criteria for selecting studies, the data sources used and the statistical methods applied in the meta-analysis which was conducted for this thesis.
The Results chapter presents findings of the present meta-analysis and on how words, pictures, and sounds contribute to semantic interference, along with the impact of moderating variables.
In the Discussion, the implications of these results for lexical access theories are explored, comparing different distractor types and suggesting directions for future research.
The Conclusion summarizes the main findings and their significance for theories of lexical access.

2. THEORETICAL BACKGROUND

Before the PWI paradigm became widely used, theories about lexical access were based on analysis of speech errors, particularly in the so-called tip-of-the-tongue (TOT) phenomenon (Dell, 1986; Burke et al., 1991; Caramazza, 1997; Levelt et al., 1999). In TOT states, speakers can typically retrieve the semantic and syntactic properties of a word but struggle to access its full phonological form (Dell, 1986, Burke et al., 1991). It is the familiar phenomenon where speakers can clearly visualize the word or describe its meaning in detail but are unable to retrieve its full pronunciation. Over time, the PWI paradigm became the preferred method for experimentally investigating the dynamics of lexical access, as it allows for better control of experimental conditions and enables researchers to test large numbers of participants using simple tasks (Spalek et al., 2013). As the roots of the PWI paradigm can be tracked back to classic interference research, the Stroop task is often considered a foundational model for understanding response competition and lexical processing (Glaser & Düngelhoff, 1984). Also, Glaser & Düngelhoff (1984) summarized various theoretical models to explain interference effects from the 1960s and 1970s. These early perspectives laid the foundation for modern accounts, including lexical competition frameworks and alternative explanations such as the REH or inhibitory control mechanisms, which will be discussed below.

Most models of lexical access assume that words are organized within a structed semantic network. This underlying structure is essential for understanding how lexical retrieval unfolds and how activation dynamics contribute to interference effects. Before discussing specific models of lexical access in detail, the following section introduces the concept of the semantic network, which provides the conceptual foundation for many of these theoretical accounts.

2.1 Semantic Network

Word production models describe how speakers access to the mental lexicon, which is the speaker's internal repertoire of words. To better conceptualize, one can imagine a spider web in which activation spreads from one concept to semantically related concepts via associative links (Collins & Loftus, 1975; Roelofs, 1992; Levelt et al., 1999). Figure 1[5] illustrates a semantic network in which concepts are represented as nodes and their semantic relationships are shown through connecting links. It provides a clear example of how activation might spread between related concepts, such as from "RED" to "FIRE", "APPLES", "ROSES", or "FIRE ENGINE which in turn may activate their own related concepts and so on (Collins & Loftus, 1975). In addition, Roelofs (1992) proposes a mechanism in which activation spreads from a picture's conceptual representation to its hypernym and then related co-hypernyms (Spalek et al., 2013). For example, in a picture naming task, speakers see a picture of a pear as the target, which activates the concept PEAR, then the hypernym FRUIT and finally the co-hypernym CHERRY as a distractor. According to Roelofs (1992) the path from PEAR to CHERRY is shorter than the reverse direction, because the target concept is already activated.

[5] Originally, the graphic represents a schematic depiction of "concept relatedness within a stereotypical fragment of human memory, with shorter lines indicating greater relatedness" (Collins & Loftus, 1975: 412). For the purposes of this thesis, it is used as an illustration of the semantic network model.

To ensure correct word selection the activation level of PEAR must exceed that of CHERRY (Roelofs, 1992). This directional asymmetry in activation becomes particularly relevant when considering the role of stimulus onset asynchrony (SOA)[6]. Depending on whether the distractor or the target is present first, the activation flows through the network differently, potentially influencing the strength of the interference effect.

Cutting and Ferreira (1999) present the lateral inhibition view. This framework posits that nodes send inhibitory signals to other nodes based on their own activation strength, resulting in direct competition. Co-activation slows down the retrieval of the target because strongly activated nodes exert more inhibition on others (Cutting & Ferreira, 1999). However, the target word can overcome this inhibition with stronger activation and external support. In this form of competition active nodes directly influence each other's level of activation, thereby affecting the retrieval speed (Cutting & Ferreira, 1999). The WEAVER++ model[7] by Levelt et al. (1999) and the lateral inhibition by Cutting and Ferreira (1999) are considered to represent the competitive lexical access view. These network dynamics form the basis for understanding how related concepts can influence naming performance, particularly in interference paradigms.

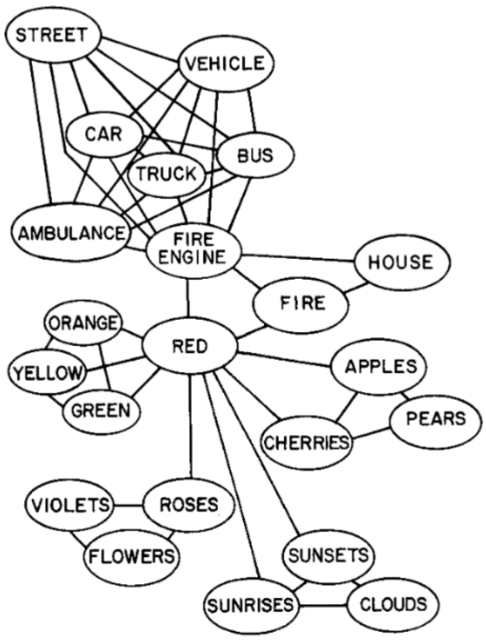


Figure 1: Illustration of the semantic network

Adapted from Collins & Loftus (1975: 412)

While models such as lateral inhibition (Cutting & Ferreira, 1999) assume increased activation of related concepts leads to direct inhibitory effects, Fuhrmeister & Bürki (2022) questioned whether the evidence for such inhibition is as robust as widely assumed. They conducted a meta-analysis to examine whether semantic interference effects in PWI tasks

[6] Stimulus Onset Asynchrony (SOA), the time interval between the onset of the distractor and the onset of the target stimulus. A negative SOA (-100 ms) means the distractor appears before the target; a positive (+100) means the target appears before the distractor.
[7] WEAVER++ = Word-from Encoding by Activation and VERification. The "++" indicates an extended version of the original WEAVER model (see also Levelt, 1989; Levelt et al., 1999.)

truly require inhibitory mechanisms or whether these effects could be explained by chance by using simulation data (Fuhrmeister & Bürki, 2022). The results showed that interference observed in slower responses can also emerge without inhibitions, simply due to the statistical properties of reaction time distributions, thus challenging the assumption of inhibitory process in naming tasks (Fuhrmeister & Bürki, 2022).

Building on this conceptualization of the semantic network, the following section outline how lexical access unfolds across difference stages according to established models of word production.

2.2 Stages of Lexical Access Processing

Various models have been proposed to describe the process involved in lexical access, including the model by Marslen-Wilson (1987) and later models by Dell & O'Seaghdha (1992), Schrief ers et al. (1990) and Levelt et al. (1999). The assumptions and mechanisms proposed in these models are central to the theoretical frameworks used in this thesis.

Marslen-Wilson's cohort model describes three central processes involved in lexical access. The process begins with the perception of the acoustic signal and its mapping onto an appropriate entry in the mental lexicon (access) followed by the selection of the best-matching word-form from the set of activated candidates (selection) and finally, the integration of syntactic and semantic context (integration) (Marslen-Wilson, 1987). Marslen-Wilson (1987) assumes that these processes run in parallel and are functionally independent of one another. This independence enables efficient processing and segmentation of the speech stream into individual words (Marslen-Wilson, 1987). In this view, contextual or semantic cues cannot pre-select certain lexical items before they have been accessed through the speech signal itself (Marslen-Wilson, 1987). Only after these lexical candidates have been activated their syntactic and semantic features can be evaluated in light of the broader sentence context (Marslen-Wilson, 1987). A key characteristic of this model (1987) is thus its strict limitation on the influence of contextual information during the early stages of lexical processing.

In contrast, Dell & O'Seaghdha (1992) developed an interactive model focusing on the process involved in word production. It shows that semantic and phonological information are closely connected during speaking and can influence each other (Dell & O'Seaghdha, 1992). The model explores whether the meaning of a word and its phonological form are processed at the same time or one after the other. The authors were also interested in how far in advance speakers plan the words they want to say. The model distinguishes between two main steps in word retrieval. First, the lemma is activated, this includes the meaning of the word along with its grammatical information (Dell & O'Seaghdha, 1992). Second, the phonological form is retrieved and prepared for articulation (Dell & O'Seaghdha, 1992). Even though these steps follow one another, they are not completely separate from each other. In some way these two levels interact with each other. This interaction was observed in Dell & O'Seaghdha (1992) experiments with word naming and lexical decision tasks, where errors by speakers were made, which they called "mixed errors" (Dell & O'Seaghdha, 1992: 296). These are errors in which speakers say a word that is phonologically and semantically related to the target, for example "rat" instead of "cat" (Dell & O'Seaghdha, 1992). Such *mixed errors* suggest that meaning and form are not processed entirely independently. The model by Dell & O'Seaghdha (1992) therefore provides a plausible explanation for mixed interference effects, such as those observed in the PWI paradigms (Dell, 1986; Damian & Martin, 1999; Mahon et al, 2007). Although it does not assume direct competition between word candidates, it still accounts for these effects through overlapping activation in the mental lexicon.

While Dell & Seaghdha's model (1992) emphasizes interaction between meaning and form, Schriefers et al. (1990) provided experimental findings using sounds as distractors instead of words, leading to interference in word production. Their study offered empirical support for the concept of lexical competition within the PWI paradigm. Based on their findings, they proposed the two-stage model of lexical access, which assumes that word retrieval occurs in two independent but serial steps (Schriefers et al., 1990). First stage represents the lemma, containing the syntactic and semantic properties of a word, followed by the retrieval of the phonological word form (lexeme) (Schriefers et al., 1990). Also, semantically related distractors which is presented 150 msec before the target picture leads to interference, while phonologically related distractors tend to facilitate the response latency (Schriefers et al., 1990). These findings support the view that semantic and phonological processes take place at different stages of lexical access.

The concept of the two-stage model of lexical access (Schriefers et al., 1990) was further developed by Levelt, Roelofs and Meyer (1999) into a computational network named the WEAVER++ model, which is a feedforward network for lexical access in speech production. The model assumes that activation spreads from conceptual representation to lemmas and then to word form in a strictly serial order (Levelt et al., 1999). Crucially, there are no inhibitory links between competing units that actively supress each other. Rather, the units compete with one another until the most strongly unit is chosen. As Levelt et al. (1999) mention, the WEAVER++ model could be used to circumvent the *hyperonym problem*[8], which challenges models of lexical access. Therefore, Levelt et al. (1999) assume that semantic activation alone cannot determine lexical selection. The reason for this could be the lexical selection mechanism, which ensures that the target is selected, since it receives the full amount of activation, whereas neighbouring activated lemmata receive only a portion of it (Levelt et al., 1999). As a result, the intended word is selected even when its hypernyms are also active.

To sum up, Marslen-Wilson's model (1987) focuses on comprehension and assumes strictly parallel, independent processing stages, whereas Schriefers et al. (1990) and Levelt et al. (1999) propose a serial, feedforward stages in production, with Levelt emphasizing competitive selection. In contrast, Dell & O'Seaghdha (1992) argue for interactive processing, where semantic and phonological levels influence each other, explaining phenomena like mixed errors.

[8] Hyperonym problem: When a concept such as "poodle" is activated, it automatically co-activates its superordinate categories such as dog and animal, because the semantic features of dog and animal are included in the subordinate concept of "poodle". Interestingly, naming studies have shown that participants rarely produce a hyperonym, for instance dog, when intending to say a specific word, for instance, poodle (Levelt et al., 1999).

2.3 Semantic Interference and Its Theoretical Consequences

Levelt et al. (1999) defines semantic interference as "the difference between the naming latencies with semantically related and unrelated distractors" (Levelt et al., 1999: 9). The REH (Finkbeiner & Caramazza, 2006; Janssen et al., 2008) offers an explanation for semantic interference effect, which does not align with the competitive view. According to their perspective the effect arises at the level of post-lexical (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007). Here, interference occurs because the distractor must be removed from the "response buffer" before the target word can be articulated (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007). For better understanding, the response buffer can be visualized using a simple analogy, namely a turnstile as known from certain stadium gate or border crossings, which allow only one person with a valid ticket to pass through at a time. In the context of word production, both the target and the distractor approach the turnstile simultaneously attempting to gain entry. However, only the word with the correct *ticket* that is relevant for articulation can pass through. The invalid ticket, in this case the distractor, would cause a delay. If the target word arrives first with a valid ticket, it smoothly moves through the turnstile, allowing for a fluent response (facilitation). However, if the distractor reaches the turnstile first, but its ticket is invalid, meaning it is not the intended response, the system must first reject and remove the distractor before allowing the target word to pass (interference). However, according to the REH a facilitation effect should be observed when multiple semantically or phonologically related representations are activated simultaneously, as these may support each other and thus speed up the selection of the target word (Finkbeiner & Caramazza, 2006b, Mahon et al., 2007). Furthermore, unrelated distractors do not even try to enter the response buffer (Mahon et al., 2007). This explains why categorically related distractors cause interference, while unrelated distractors do not affect response times. When the distractor enters the response buffer instead of the target, it may delay the response or result in a speech error (Mahon et al. 2007; Spalek et al. 2013). Interestingly, one might ask, how the REH accounts for cases in which the target rather than distractor enters the output buffer. In such cases, the account assumes that the decision mechanism can determine whether the current response in the buffer originates from the target picture or the distractor word (Mahon et al., 2007; Mulatti & Coltheart, 2011). Or as Mahon et al. (2007: 524) put it: "[…] the decision mechanism that clears the output buffer of nontarget words is sensitive to the provenance of the representations over which it operates". In the non-competitive framework, competition is not considered relevant during lexical access at all (Dell, 1986). Instead, the target word is selected by the highest activation, regardless of how many other words are co-activated or how small the differences in activation might be (Dell, 1986; Spalek et al. 2013). Over time Dell's (1986) model of spreading activation has been used and cited as a representative of non-competitive approaches to lexical access. In contrast to competition approaches, interference effects are interpreted not as the result of lexical competition but as a natural outcome resulting in a speech error, as Dell (1986: 290) put it: "Errors are the natural consequences of the theory's assumptions. It just so happens that, on occasion, incorrect items have higher activation levels than correct ones and are selected". Assuming a scenario in which a speaker intends to produce a specific word in a given context. One could argue that there is no competition at all, otherwise speakers would not be able to speak fluently and would need much more time to articulate a single word. From this perspective, each word has the same potential to be selected by the speaker. This aspect is also reflected in Spalek et al. (2013), who describe the view that according to non-competitive models, speed at which the target is retrieved is not slowed down by other activated words (Spalek et al., 2013). Thus, the question arises whether speed plays a crucial role according to semantic interference effect (Spalek et al., 2013). The non-competitive account assumes that the word that is most relevant or fastest to access will be articulated (Dell, 1986). In their view, speed is not reduced by competition but rather determined by how quickly a lexical unit reaches a threshold for articulation (Dell, 1986). In other words, the fastest suitable candidate is selected without a need to "win" a competition. Similarly, the REH (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007; Janssen et al., 2008) assumes that distractors do not compete at the lemma level but are excluded at post-lexical level.

So far, each of these accounts makes different assumptions about the level at which lexical access takes place. The competitive approach assumes that selection occurs at the lexical level, with the most strongly activated lemma being selected (Levelt et al., 1999). In contrast, the REH locates selection at a post-lexical stage, specifically within the response buffer (Mahon et al., 2007). A crucial factor in distinguishing between the approaches of competitive and non-competitive lexical access is the role of relevance of an item (Spalek et., 2013). The REH argues it is not competition but relevance that determines whether a word is excluded from the response buffer, such as an unrelated distractor (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007). A similar mechanism can be observed in the Stroop effect[9], where irrelevant information (written word) is processed before the relevant information (ink colour) can be named (MacLeod, 2015). However, the motor theory of speech perception (Liberman & Mattingly 1985) suggests that spoken words are automatically linked to articulatory codes. This aligns with the assumptions of the REH, which states that every word has access to the response buffer, including distractors, which can enter the buffer before the target word. This is referred to as "privileged access" (Spalek et al. 2013: 601). Important to note, the REH does not clearly explain when a semantic related distractor enters the response buffer and when it does not (Spalek et al. 2013). In this regard, the competitive approach has an advantage. Unlike the REH, it does not rely on a response buffer but rather assumes that word retrieval is determined by the activation levels of competing lexical entries (Levelt el., 1999).

Based on the mentioned frameworks, lexical access can be described in one of four ways, First, as an *indirect competition*, where the critical difference between target word and other co-activated words must be exceeded (WEAVER++ model by Levelt et al. 1999). Second, as an inhibitory mechanism (*direct competition*), where retrieval of the target word is slowed down by co-activation due to lateral inhibition (Cutting & Ferreira 1999). Third, as a non-competitive way, where the target word is selected based on the highest activation level, unaffected by the activation of other words (Dell et al. 1986). Fourth, as a post-lexical process, where competition occurs at a level of a response buffer, with a focus on response relevance rather than competition (Mahon et al. 2007). While these models offer explanations for lexical access, their core assumptions are challenged by empirical data from naming

[9] The Stroop effect describes the increased difficulty in naming the colour of the ink when it differs from the meaning of the word (e.g., the word "blue" printed in red ink), see also Stroop (1935).

studies with various modifications. The following section outlines key challenges to the competitive view that will be further examined in Section

5.4.2 Challenges for the Competitive View and Response Exclusion Hypothesis.

To summarize the core distinctions, the table below outlines how each model conceptualizes lexical access and accounts for interference effects.

Table 1: Overview of theoretical models in lexical access

Model	**level of selection**	**selection mechanism**	**semantic interference**
Competitive	lemma level	strongest activation, words compete	arises from competition between co-activated items
Response Exclusion Hypothesis	post-lexical level	response relevance	distractor enters output buffer before target
Non-Competitive	lexical level	highest activation, no competition	results from random speech errors

2.4 Theoretical Challenges to the Competitive Approach

Some findings from modified picture naming studies challenge the notion of purely competitive lexical selection. Both, interference and facilitation effects have been observed, depending on the nature of the semantic relationship between target and distractor (Sailer et al., 2009). Interference typically arises with categorically related distractors (Cutting and Ferreira, 1999), while facilitation has been reported when distractors are masked or differ in semantic nature (Finkbeiner & Caramazza 2006b; Mahon et al., 2007). Further variations of the picture naming paradigm provide additional challenge against competitive lexical selection. In delayed naming tasks, where the distractor follows the picture, interference effects persist, suggesting post-lexical processing rather than competition at the lexical level (Janssen et al., 2008). Similarly, the distractor frequency effect, where high-frequency distractors cause less interference than low-frequency ones, contradicts predictions from competitive models but can be accounted for by the response buffer mechanism (Finkbeiner & Caramazza, 2006a; Mahon et al., 2007). Furthermore, findings on semantic distance challenge the competitive selection account. The REH assumes, that strongly related distractors facilitate target retrieval due to shared semantic features, whereas weakly related distractors are less supportive at the conceptual level and this are more likely to cause interference (Mahon et al., 2007). As a result, weakly related distractors causing stronger interference (Finkbeiner & Caramazza, 2006a).

Moreover, studies comparing masked versus visible distractors reveal that categorically related distractors cause interference when distractors are clearly visible but facilitation when masked (Finkbeiner & Caramazza, 2006b). This pattern is difficult to reconcile with a strictly competitive selection process but aligns with the REH. In their view, visible distractors must be removed from the response buffer before the target can be named, whereas masked distractors are too weak to engage response selection but still activate semantically related representations, leading to facilitation (Finkbeiner & Caramazza, 2006b). Taken together, the findings suggests that semantic interference effects in word production do not exclusively rely on lexical competition. Notably, the findings on naming studies do not definitely favour one theoretical account over another, as all mentioned frameworks above can explain certain pattern while failing to account for others.

Given these inconsistencies, the present meta-analysis systematically analyses previous studies in order to provide deeper insights into the mechanisms underlying semantic interference in standard picture naming studies.

3. METHODOLOGY

3.1 Study Identification and Selection Process

In the context of this master's thesis, a meta-analysis was conducted to investigate whether semantic interference in picture naming studies is dependent on the type of distractor.

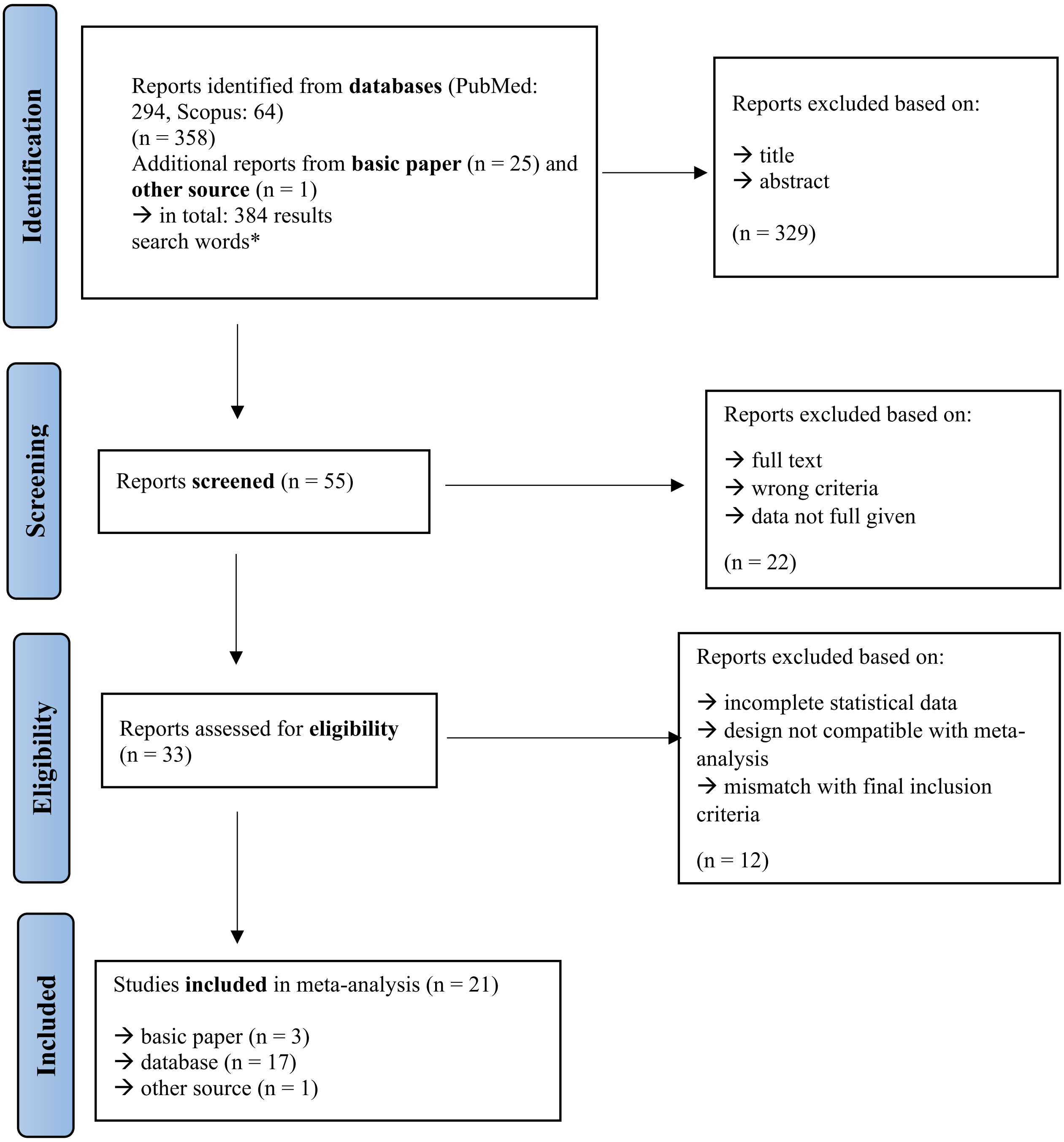
The preparation followed a systematic approach based on the PRISMA[10] guidelines to ensure the inclusion of relevant and peer-reviewed studies. The first step involved an extensive literature search using two databases, PubMed and Scopus, which were used based on positive experiences in previous works. In addition to database searches, other resources were consulted, such as Spalek et al. (2013), which served as a basic paper due its well-structured and comprehensive overview of the topic and its presents different approaches to competitive and non-competitive lexical access. Furthermore, an external source like Navarrete & Costa (2005) was also included.

To maximize coverage, predefined search terms were applied, ensuring the retrieval of studies examining semantic interference effects in picture naming tasks with different types of distractors words, sounds and pictures. These keywords were combined into two- or three-word phrases to narrow down the search results and avoid retrieving over 1000 studies, which would have exceeded the scope of this thesis. The keywords used across both databases included "picture naming task", "picture word interference", "picture–picture paradigm", "picture sound interference", "environmental sounds", "semantic interference", "lexical access" and "lexical competition". To ensure that the keyword "semantic interference" appeared in combination with terms related to the task type, phrases such as "picture naming task", as well as terms describing the type of distractor, such as "picture-word interference", "picture-sound interference or environmental sounds" and "picture-picture paradigm" were included. For example, a specific keyword combination used to find picture-sound studies was "*picture naming task*" AND "*environmental sounds*".

In total, 384 reports were identified through different sources. Of these, 358 were retrieved from database searches, 294 from PubMed and 64 from Scopus. An additional 25 reports were obtained from the basic paper (Spalek et al., 2013), and one report was retrieved from another source (Navarrete & Costa, 2005).

[10] PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

3.2 PRISMA Flow Diagram



*Search words: picture naming task, picture word interference, picture–picture paradigm, picture sound interference, lexical access, lexical competition, semantic interference

Figure 2: PRISMA Flow Diagramm

3.3 Screening and Eligibility Assessment

Following the identification phase, all retrieved studies underwent a structured screening process. During the screening process, titles and abstracts of the 384 reports were reviewed for relevance. Based on predefined exclusion criteria, 329 reports were excluded due to irrelevance to the research topic. Subsequently, 55 full-text reports were assessed for eligibility. Of these, 33 were further reviewed, and 22 reports were excluded for one or more of the following reasons that they did not meet the inclusion criteria, required data were not provided for statistical analysis or the full text did not contain sufficient methodological details. An additional twelve were excluded based on incomplete statistical data, incompatible design, or a mismatch with the final inclusion criteria. In total, 21 studies (k = 21) were included in the final meta-analysis, comprising 37 experiments. Of these studies three came from the basic paper (Spalek et al., 2013), one from external source (Navarrete & Costa, 2005) and 17 were identified through database searches. The studies were categorized based on the modality of the distractor used in the experiments. For the analysis 16 studies included word distractors, four included sound distractors and four included picture distractors. Three studies contributed to more than one category, as they included both word and picture in separate experiments. Importantly, all experiments included in the analysis were conducted with independent participant samples, meaning that the same individuals were not tested across different distractor conditions.

3.4 Inclusion criteria

To ensure methodological consistency, a set of inclusion and exclusion criteria was established. There criteria were applied during the eligibility assessment phase, after an initial screening of titles and abstracts had been conducted to remove clearly irrelevant studies. Once studies passed this preliminary screening, they were further evaluated based on the following predefined criteria.

3.4.1 Experimental Design

Studies were included if they investigated picture naming tasks, in which the target was always a picture, while distractor was presented in one of three modalities that are word, sound or picture. The experiments were categorized into three main types:

3.4.1.1 Picture-Word Interference (PWI) Studies:
The target picture and the distractor word were presented either simultaneously or at different time intervals (SOA) on a screen.

3.4.1.2 Picture-Sound Interference (PSI) Studies:
The target picture was displayed on the screen while participants heard either simultaneously or at different time intervals a sound through headphones.

3.4.1.3 Picture-Picture Interference (PPI) Studies:
Due to the limited number of PPI studies, different designs were accepted in this category. For example, in some studies, a cue such as an arrow indicated the target picture after the distractor picture had appeared. In other designs, the target picture was highlighted by a specific-coloured frame, while the distractor was presented in a different colour, such as blue (Matushanskaya et al., 2020).

The dependent variable in all studies was reaction time, while the independent variable was the type of distractor. Distractors were further categorized into semantically related and unrelated to the target picture. Within each study, semantic interference was derived by comparing reaction times between these two conditions.

3.4.2 Stimulus Onset Asynchrony (SOA)

Another inclusion criterion was the presence of the SOA manipulation, as PWI studies are characterized by the fact that the target and distractor do not necessarily appear at the same time. Instead, they may be presented with a short time delay, where either the target appears first, followed by the distractor or vice versa. For this meta-analysis, a SOA interval within the range of -200 msec to +100 msec were selected, specifically -200 msec, -100 msec, 0 msec, and +100 msec. This decision was based on previous findings in the literature showing that semantic interference effects between related and unrelated distractors are typically observed within this time window (Glaser & Düngelhoff, 1984; Roelofs, 1992; Sailor et al., 2009; Mädebach et al., 2011; Shao et al., 2013). For this reason, the same time window was used to examine whether similar effect could also be observed for sound and pictures distractors. Moreover, this SOA range aligns with the core prediction of the REH, which assumes that semantic interference can only occur when word distractors directly interfere with articulation. In order to provide a meaningful comparison between distractor types, only studies using sound and picture distractors that used SOAs within the same range were included in the analysis. However, it was not required that all five SOA conditions be present in a single study. Studies that tested only a subset of these intervals, for example, -100msec, 0msec and +100msec, were also included.

3.4.3 Position of the Distractor

The spatial position of the distractor was not a determining factor for study inclusion. The target and distractor could be placed side by side, or in PWI studies, the distractor word could be embedded within the picture. These criteria ensured that methodologically comparable studies were included in the meta-analysis, thereby enhancing the validity and reliability of the results.
For illustrative purposes, two examples from the PWI and PPI paradigms are shown below.

Picture-Word Interference illustration:

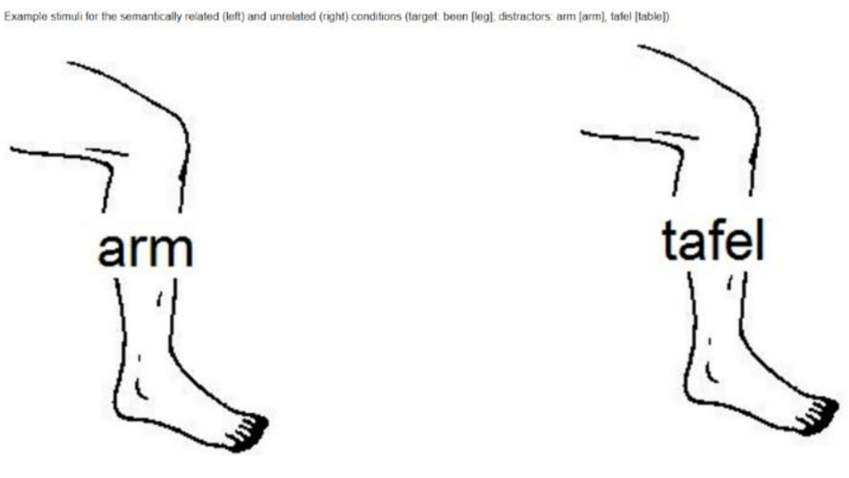


Figure 3: Example of the two Picture-Word Interference conditions

Figure 3 shows an example of a semantically related vs. unrelated distractor
Adapted from Vromans RD, Jongman SR (2018: 6). The interplay between selective and nonselective inhibition during single word production. PLoS ONE 13(5): e0197313. https://doi.org/10.1371/journal.pone.0197313

Picture-Picture Interference illustration:

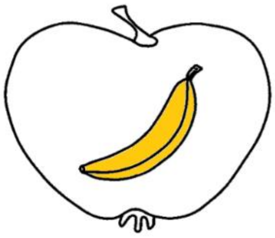


Figure 4: Example of the Picture-Picture Interference

Figure 4 shows an Example of a semantically related distractor.
Adapted from Damian & Bowers (2003: 113). Locus of semantic interference in picture–word interference tasks. Psychonomic Bulletin & Review 10(1). 113.
Note: Image adapted from Damian & Bowers (2003) with independent colour modification of the target picture (banana) for illustrative purposes.

3.4.4 Familiarization

The current meta-analysis included only studies that implemented a familiarization phase, in order to ensure the comparability and consistency of results across experiments. This inclusion was further supported by the study of Gauvin et al. (2018) who demonstrated that familiarization plays a crucial role in the emergence of semantic interference effects.

3.4.5 Participant Age

Although semantic interference occurs independently of age (Feyereisen et al., 1998), this meta-analysis focused on participants between the ages of 18 and 50. By restricting the age range to 18-50 years, this meta-analysis ensures a more homogeneous sample, minimizing confounding effects related to cognitive development or decline. The gender of the participants was not considered relevant for the analysis

3.5 Exclusion Criteria

This meta-analysis focuses on standard picture naming tasks and excludes studies with specific design modifications. Excluded studies include priming studies, where stimuli were shown before the distractor to influence lexical activation, as well as studies, where participants were not required to name the target but instead had to point to it or select it using a key press. Studies where the target was not a picture were also excluded.
Additionally, studies using the delayed PWI paradigm, which involve intentionally delaying the naming responses, were excluded as they did not meet the inclusion criteria.
Further, studies including experiments that examine distractor frequency effects, where high- and low-frequency distractors influence interference differently (Miozzo & Caramazza, 2003) were also excluded.

Moreover, masked distractor studies, where distractors are briefly presented and then hidden, were excluded (Finkbeiner & Caramazza, 2006), as they introduce different processing mechanisms. Similarly, semantic distance manipulations, which compare interference from closely vs. distantly related distractors (Mahon et al., 2007), were excluded, as they introduce conceptual priming effects beyond standard PWI interference.
Also, to ensure methodological consistency, studies involving children and adolescents under the age of 18 were excluded, as their cognitive and linguistic processing is still developing, which could introduce additional variability in reaction times and lexical access (Feyereisen et al., 1998). Similarly, studies with elderly adults were excluded due to potential age-related cognitive slowing and motor delays, which could systematically influence response times. In summary, studies were excluded if their experimental design deviated from the established inclusion criteria.

3.6. Data Extraction and Coding

To systematically organize the extracted data for the meta-analysis, a structured Excel spreadsheet was created. The table included key variables from each study to ensure a consistent and comprehensive dataset for further statistical analysis.

3.6.1 Extracted Variables

For each included study, relevant variables were systematically recorded to ensure consistency in data extraction. The dataset included general study information such as authors, year of publication, study title, sample size and distractor. Accordingly, picture naming studies using word, sound or picture as distractor were marked in the table as w, s, and p, respectively.

To account for SOA, studies were included if they examined at least one of the following SOA values, such as -200 msec, -100 msec, 0 msec and +100 msec. Since the correlation coefficient r was required for the analysis, efforts were made to extract this value whenever possible. In cases where r was not reported directly, it was computed based on other available statistics, such as t-values and degrees of freedom.

The dependent variable extracted from each study included mean reaction time (RT) for both semantically related and unrelated distractors. Additionally, for each study, the mean (mr for related condition, mu for unrelated condition), standard deviation (sdr and sdu), and standard error of the mean (semr and semu) were recorded, if available. If only the standard deviation was reported alongside the mean, the missing value was calculated using the appropriate statistical formulas (Harrer et al. 2021). This step was essential to derive standardized effect sizes, such as Cohen's d and Hedges' g.

To ensure methodological rigor and consistency, the entire process of data extraction and coding was carried out following the guidelines of Harrer et al. (2021), who provide a detailed step-by-step framework for performing meta-analysis and calculating effect sizes and statistical parameters (for more details, see Harrer et al. 2021).

3.6.2 Data Structure and Organization

The Excel table was designed with each row representing a single experimental condition within a study and each column representing a specific variable. For studies that included multiple SOA conditions or distractor types, these values were recorded within a single “soa” and “distractor” with each experiment represented in a separate row. This structure ensured that all relevant comparisons were systematically documented while maintaining a clear and organized dataset.

For illustrative purposes, an excerpt from the dataset is provided in the appendix to visualize the structure of the extracted data as recorded in Excel.

3.6.3 The Choice of Effect Size and Random Effect Model

To quantify semantic interference effects across studies, Hedges’ g was calculated for each individual study based on means, standard deviations and sample sizes for semantically related and unrelated distractor conditions. Hedges’ g was chosen because it provides and a more unbiased estimate of the standardized mean difference, especially in studies with small sample sizes. The meta-analysis was conducted using a random effect model to account for heterogeneity between studies. Hedges’ g values (g) and their corresponding standard errors (seTE) were entered into the analysis using the *metagen* function from R package meta (Schwarzer et al., 2007), specifying standardized mean differences (SMD) as the effect size metric.

3.6.3 Statistical Analysis in R

The analysis was conducted using the software R version 4.3.2 (R Core Team, 2023) via RStudio version 2024.12.1+563. The statistical analysis, including effect size calculations and meta-analytic models, was carried out using R packages meta and dmetar (Schwarzer et al., 2007; Harrer et al., 2021), following the methodological guidelines outlined by Harrer et al. (2021). The extracted data, which had been systematically recorded in an Excel spreadsheet were imported into R for further processing. This dataset included key variables such as study characteristics, experimental conditions, mean values, standard deviations, standard errors, SOA conditions and correlation coefficients. Studies that lacked essential statistical data were excluded. In summary, after ensuring methodological consistency and calculating effect sizes, the dataset was prepared for statistical analysis. The following section presents the results of the meta-analysis, focusing on the effects of distractor type, SOA and potential new insights compared to previous findings in the literature.

4. RESULTS

This section presents the results of the meta-analysis, focusing on the impact of distractor type on semantic interference. The findings include overall effect sizes, heterogeneity measures and potential moderators, SOA, influencing the observed effects. For clarity, effect sizes and confidence intervals are primarily visualized through forest plots, as they provide a direct comparison of individual studies and an overall pooled estimate.

4.1 Overall effect size

The meta-analysis included 37 effect sizes from picture naming task experiments (k = 21) that compared reaction times between semantically related and unrelated distractors. The forest plot displays the individual effect sizes (Hedges' g)[11] along with their 95% confidence intervals. The pooled effect size, calculated using a random-effects model, is g = 0.27 with a 95% confidence interval of [0.16; 0.37, $p < 0.01$]. This indicates a small to moderate interference effect, which is statistically significant. The analysis also reveals moderate heterogeneity between studies ($I^2 = 51.3\%$, p = .0002). In PPI studies no effects were found, while the PSI studies reported positive but non-significant effects. These differences in distractor types likely contributed to the variability in effect sizes, as given in the relatively wide prediction interval of [-0.17; 0.70].

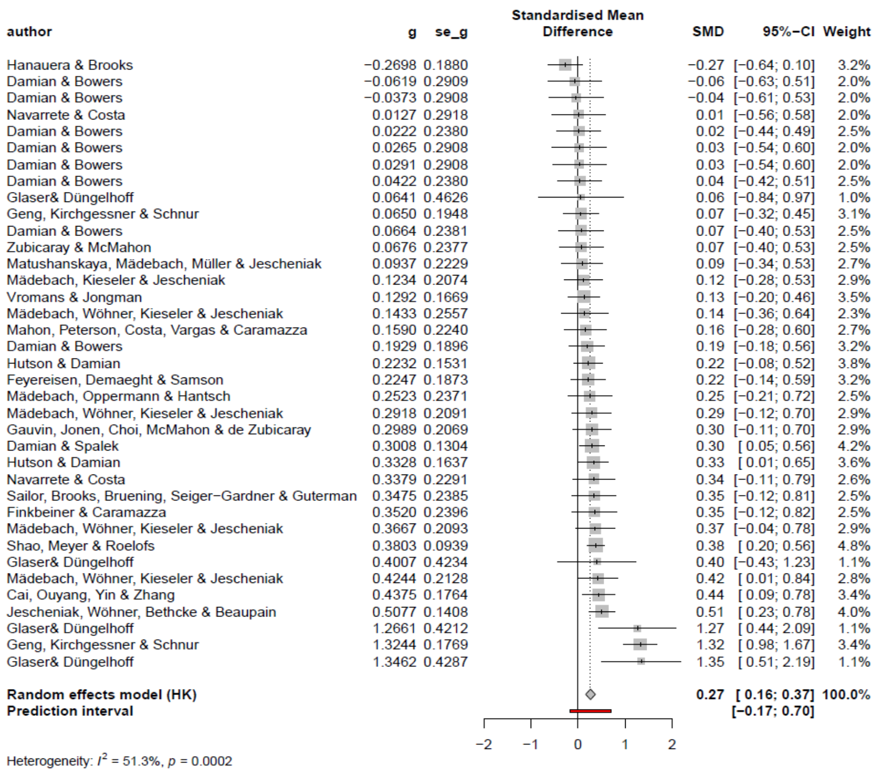


Figure 5: Forest Plot Overall Effect Size

[11] For interpretation, Hedges' *g* values around 0.20 are typically considered small effects, around 0.50 medium effects and around 0.80 large effects (Brydges, C.R., 2019).

4.2 Subgroup Analysis: Distractor

To examine potential differences in the strength of the interference effect depending on the type of semantic distractor, a subgroup analysis was conducted. The studies were divided into three groups based on the modality of the distractor: word (w), sound (s), and picture (p). The analysis shows that the interference effect is most pronounced in studies using words as distractors. The pooled effect size was g = 0.36, with a 95% confidence interval of [0.22; 0.50], k = 16, indicating a significant and moderate effect. In contrast, studies with sound distractors showed non-significant effect (g = 0.16, 95% CI: [-0.07; 0.38], k = 4). For picture distractors no interference effect was found (g = 0.03, 95% CI: [-0.02; 0.08], k = 4). To examine whether effect sizes differ between groups, Cochran's Q-test was applied. Its value is Q = 21.87, df = 2, p < .0001, indicating statistically significant differences between distractor types.

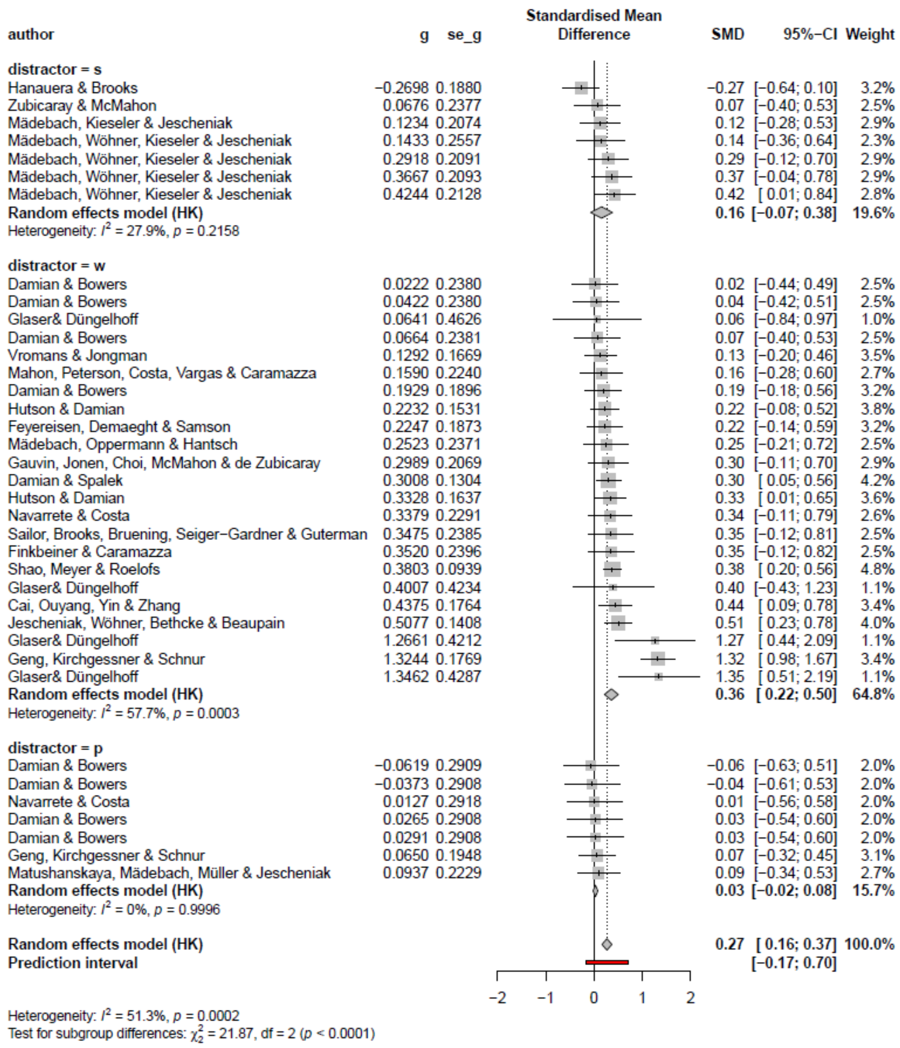


Figure 6: Forest Plot Subgroup Analysis: Distractor

In addition to the subgroup comparison, each distractor type was analysed separately using a random-effects model. This method allows for a clearer understanding of the strength and consistency of the interference effect in each group of distractors.

4.2.1 Distractor Word:

For word distractors, the pooled effect size was g = 0.36 with a 95% confidence interval of [0.22; 0.50], indicating a significant and moderate semantic interference effect. The prediction interval ranged from [-0.14 to 0.86], suggesting that future studies may observe both weaker and stronger effects. Although the interference effect for word distractors can overall be classified as moderate and significant, both the subgroup analysis and the separate examination of these studies reveal considerable heterogeneity ($I^2 = 51.3\%$, p = .0002)[12]. This suggests that the effect sizes are not consistently stable across studies but vary depending on the individual study.

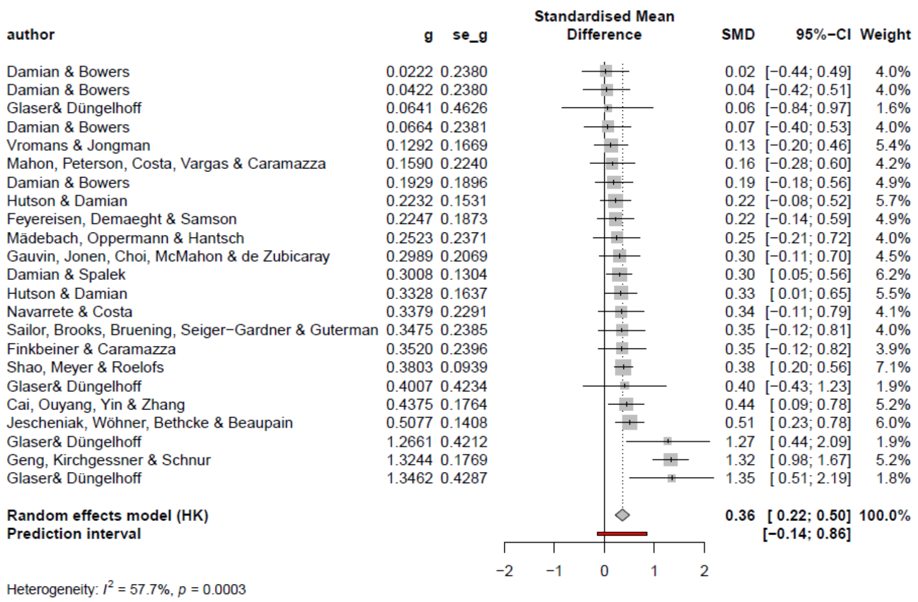


Figure 7: Forest Plot Words

4.2.2 Distractor Sound:

For sound distractors, the pooled effect size was g = 0.16 with a 95% confidence interval of [-0.07; 0.38], indicating a small positive semantic interference effect that did not reach statistical significance. The prediction interval ranged from [-0.28 to 0.59], suggesting that future studies may observe both weaker and stronger effects. The heterogeneity was low to moderate ($I^2 = 27.9\%$, p = 0.2158) and was identical in both the subgroup analysis and the separate model.

[12] I^2 values of approximately 25%, 50% and 75% are typically interpreted as indicators of low, moderate and high heterogeneity.

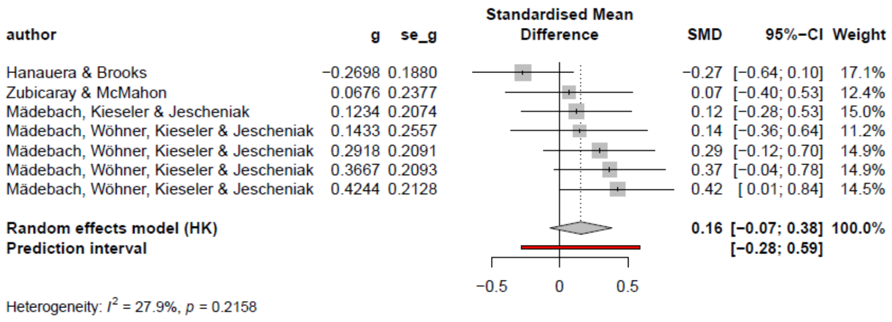


Figure 8: Forest Plot Sounds

4.2.3 Distractor Picture:

For picture distractors, the pooled effect size was g = 0.03 with a 95% confidence interval of [-0.02; 0.08], indicating no significant semantic interference effect. The prediction interval ranged from [-0.21 to 0.27], suggesting that future studies are also likely to find null or only very weak effects. The heterogeneity was zero (I^2 = 0.0%, p = 0.9996), both in the subgroup analysis and in the separate model.

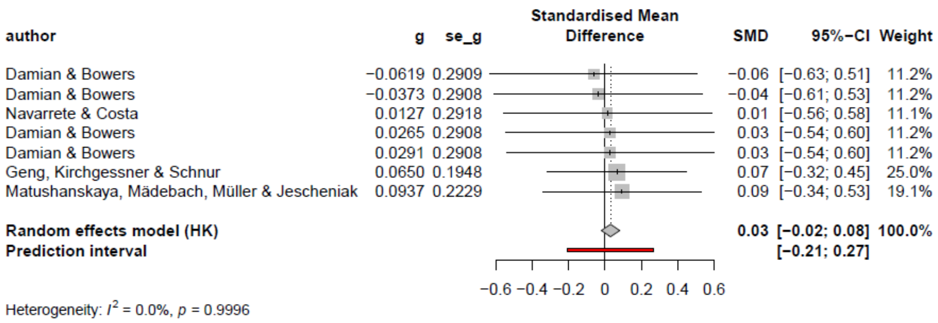


Figure 9: Forest Plot Pictures

These separate analyses confirmed the results obtained in the subgroup analysis and allowed for a more detailed presentation of the effect sizes, confidence intervals, prediction intervals and heterogeneity for each group.[13][14]

[13] In the separate forest plots for distractors (Figures 8-10), the CI-weights (percentage contributions) of individuals studies appear higher than in the overall plot (Figure 7), as the weighting is distributed solely among the studies within each subgroup. This has no effect on the calculated effect sizes or confidence intervals.
The prediction intervals in the subgroup plots (Figures 8-10) are narrower and more specific than in the overall plot (Figure 7), as they reflect only the variance within each distractor type.

[14] The analysis of picture distractors revealed a non-significant effect (g = 0.03, 95% CI: [-0.02; 0.08]), with an I^2 value of 0%. While I^2 of 0% suggest that the observed variability between studies is entirely attributable to sampling error rather than true heterogeneity, this should be interpreted with caution due to the small number of included studies. The absence of observed heterogeneity may reflect limited statistical power to detect true between-study differences.

4.3 Subgroup Analysis: SOA

To examine the timing of the semantic interference effect, a subgroup analysis was conducted based on the SOA. The analysed conditions included -200 msec, -100 msec, 0 msec and +100 msec. Even though some SOA conditions showed larger or smaller effects than others, the overall variation was not statistically significant, as the Q-test ($Q = 1.34$, $df = 3$, $p = .72$) indicated no significant difference between the groups. The largest and statistically significant effect was observed at SOA = 0 msec ($g = 0.29$, 95% confidence interval: [0.15; 0.42], $k = 25$), and moderate heterogeneity ($I^2 = 60.8\%$). Small effects were also found for SOA = -200 msec and -100 msec ($g = 0.24$, $k = 5$; and $g = 0.16$, $k = 4$, respectively), but these were not statistically significant. At SOA = +100 msec, the effect size was higher ($g = 0.38$, $k = 3$), but the result was not statistically significant due to the very wide confidence interval [-1.33; 2.08] and high heterogeneity ($I^2 = 72.6\%$).

The strongest semantic interference effect was observed at an SOA of +100 msec ($g = 0.38$). However, this estimate is based on only three studies and should therefore be interpreted with caution. In contrast, the estimate for SOA = 0 msec ($g = 0.29$) is based on a much larger number of studies ($k = 25$) and may thus provide a more robust indication of the typical interference effect at this timing. Overall, the results suggest that the semantic interference effect occurs relatively consistently over time, especially in the case of simultaneous presentation. However, the observed differences between SOA conditions are not statistically conclusive, which may be due to the small number of studies available for the other SOA conditions. This imbalance was not due to intentional selection, but rather the result of strict inclusion criteria, which led to the exclusion of a considerable number of studies.

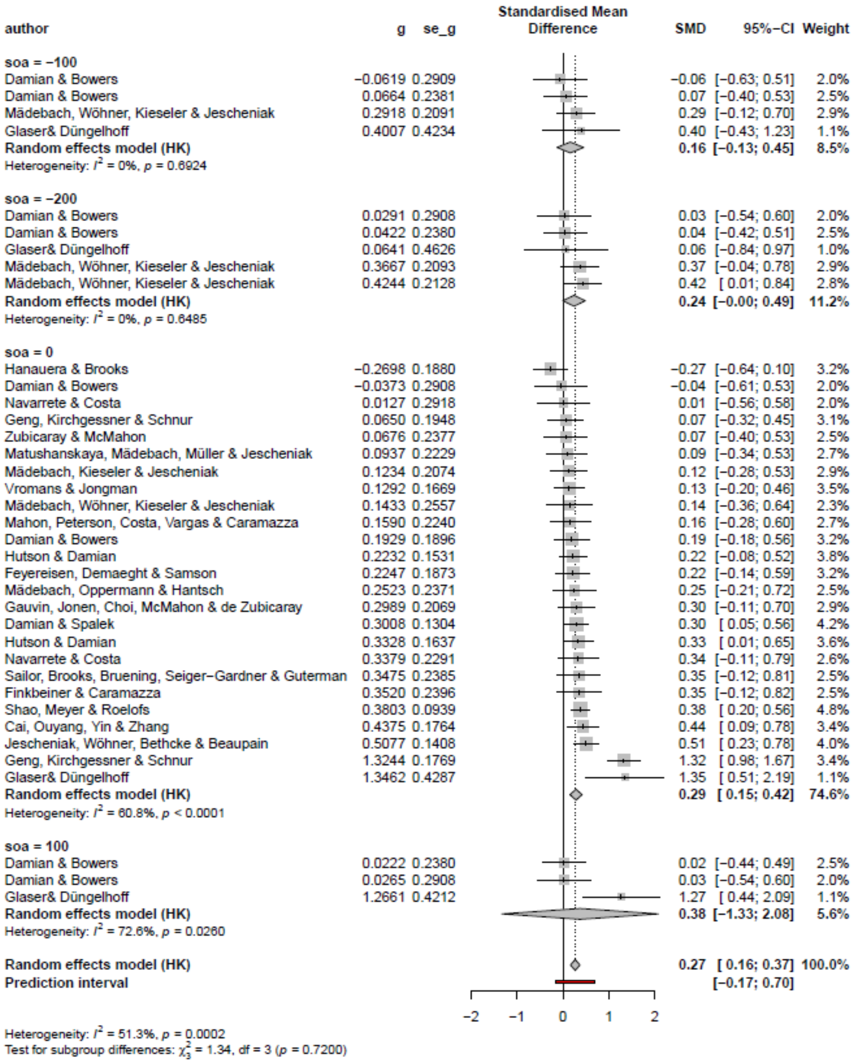


Figure 10: Subgroup Analysis SOA

4.4 Error Rates

To determine at which SOA, with which type of distractor, and under which condition participants experienced the greatest difficulty, error rates were also included in the analysis.

4.4.1 Effect of Distractor Type on Error Rates: Semantically Related vs. Unrelated

Table 2: Effect of Distractor Type on Error Rates

Distractor	Error Difference
w	1.13
s	-0.35
p	0.15

The analysis of error differences illustrated in Table 2 shows that semantically related words led to significantly more errors than unrelated words. This strong effect highlights the high level of interference caused by word distractors. For picture distractors, the difference was very small, which is consistent with the reaction time data. Surprisingly, a negative error difference (–0.35%) was observed for sound distractors suggesting that semantically related sounds might not have been more disruptive and may even have been easier to ignore.[15] However, this result should be interpreted with caution, as it is likely based on a small number of studies.[16]

4.4.2 Error Mean by Distractor

Table 3: Error Mean by Distractor

Distractor	Error Mean
w	3.7
s	2.87
p	3.05

Independent of the distractor's semantic relatedness, the mean error rates across distractor types in Table 3 show that word distractors were associated with the highest overall error rate (3.70%), followed by picture and sound distractors.

4.4.3 Error Difference by SOA: Semantically Related vs. Unrelated Distractors

Table 4: Error Difference by SOA

SOA	Error Difference
-200	0.06
-100	0.275
0	0.95
100	0.46

As in Table 4 illustrated, the largest difference in error rates and thus the strongest interference effect based on errors was observed at SOA of 0 msec. In this condition, participants made on average 0.95% more errors when the distractor was semantically related. Effects were also found at SOA = +100 msec and -100 msec. At SOA of -200 msec, however, the effect was almost negligible (0.06%), suggesting that distractors presented early had little impact on error rates.

4.4.4 Error Mean by SOA

Table 5: Error Mean by SOA

SOA	Error Mean
-200	2.85
-100	2.36

[15] These values are based on n = 15 studies for word distractors, n = 3 for sound distractors and n = 3 for picture distractors. The absolute difference in error rates is small in magnitude but consistent with the reaction time data.
[16] Although the absolute differences in error rates are numerically small, the observed pattern closely mirrors the results from the reaction time analysis. Word distractors lead to the strongest interference, while sound and picture distractors show minimal or no effects.

0	3.72
100	3.8

Table 5 shows that, regardless of the semantic relatedness of the distractor, the highest overall error rates were observed at SOA of +100 msec and SOA of 0 msec. In contrast, the -100 msec and –200 msec conditions showed fewer errors overall, with -100 msec having the lowest error rate. This suggests that simultaneous or later presentation of the distractor was generally more demanding or disruptive for participants, independently of the semantic interference effect.

Taken together, the error rate analyses support the findings based on reaction times and provide further insights into the role of distractor type and SOA. The strongest semantic interference in error rated occurred when semantically related word distractors were presented simultaneously with the target. Word distractors generally led to both the highest error difference and the highest overall error rate, indicating a greater semantic interference. Sound distractors, in contrast showed the lowest error rates and even a negative error difference (-0.35), suggesting they may have been easier to ignore.
However, these results should be interpreted with caution, as a substantially large number of studies using PWI paradigms were included in the analysis compared to studies using sound or picture as distractors. The lower number of PSI and PPI studies may limit the precision and generalizability of the corresponding effect estimates.

5. DISCUSSION

The present meta-analysis investigated whether semantic interference in picture naming tasks is influenced by the type of distractor. To address the main research question, a meta-analysis was conducted in which specific inclusion criteria for picture naming studies were established. Studies that met these criteria were selected for the analysis following the PRISMA guidelines. The analysis focused on studies using a SOA ranging from -200 msec to +100 msec and included different types of distractors, namely words, sounds and pictures. Hedges' g was chosen as the effect size because it provides a less biased estimate of the standardized mean difference, especially in studies with small sample sizes (< 30). The results confirm the presence of a reliable semantic interference effect when a semantically related word was used as a distractor. The moderate and statistically significant effect size ($g = 0.36$, $k = 25$) in the word condition indicates that semantically related words lead to slower response latencies. In contrast, sound distractors produced only a small, but non-significant effect ($g = 0.16$, $k = 4$). Surprisingly, the error data showed a negative error difference for sound distractors, suggesting that participants were less disrupted by the distractor. For picture distractors, no interference effect was found ($g = 0.03$, $k = 4$). This result may be explained by the fact that pictures, unlike words, do no activate lexical information in the same way (Damian & Martin, 1999). Another possible explanation is that picture distractors are more easily distinguishable and therefore easier to suppress than semantically related words (Damian & Bowers, 2003; Navarrete & Costa, 2005). Furthermore, while the overall SOA did not yield statistically significant differences, effect sizes were generally stronger at SOAs 0 msec and +100 msec, with the most robust and reliable effect at 0 msec. These findings are in line with previous findings regarding lexical competition during word production (Glaser & Düngelhoff, 1984; Roelofs, 1992; Sailor et al., 2009; Mädebach et al., 2011; Shao et al., 2013). Overall, the results revealed robust semantic interference effects for word distractors, whereas no consistent interference effect was observed for sound and picture distractors. Also, no facilitation effect was observed. These findings raise important questions regarding the mechanisms underlying semantic interference and how they may vary depending on distractor type and temporal dynamics (SOA).

The following discussion focuses on how the observed interference effects vary across different types of distractors and what these patterns imply for theories of lexical access. The chapter is structed by distractor type with separate sections for word, sound and picture distractor. For word distractors, where data coverage was most comprehensive, additional moderating factors such as familiarization, time pressure and participant age are also considered. Although the main theoretical accounts of semantic interference in picture naming tasks, particularly the debate between competitive and non-competitive models, have already been introduced in the Introduction, they are briefly revisited here to provide a framework for interpreting the findings of the present meta-analysis.

5. 1 The Picture-Word Interference paradigm

The PWI task is an established experimental method in speech production research used to examine how language processing unfolds at different stages of conceptual, lexical, and post-lexical stages. The following classifications and distinctions, such as SOA, familiarization, and time pressure, are based exclusively on studies using the PWI paradigm. These categories were not applied to PSI or PPI studies, as there were too few studies with a comparable focus in these paradigms to allow for meaningful conclusion.

5.1.1 Semantic Interference and Facilitation in PWI studies

An observed phenomenon in PWI paradigms is that semantically related distractors often lead to longer reaction times, because it is assumed that distractors compete with the target word at the lexical level and cause a semantic interference effect (Schriefers et al., 1990; Levelt et al., 1999; Mädebach & Hantsch, 2013; Spalek et al., 2013). The most common explanation follows from representatives of the lexical competition approach (Roelofs, 1992; Levelt et al., 1999) which assumes that multiple lexical nodes are activated through conceptual activation, requiring selection among competing entries. However, under certain conditions the opposite can also occur, namely semantic facilitation. This effect is typically observed when the distractor is masked and or phonological related to the target (Finkbeiner & Caramazza, 2006; Mahon et al., 2007; Janssen et al., 2008), precedes the target picture by 400 msec or more (Sailor et al., 2009) or when there is an associative relationship between the distractor and the target (Cutting & Ferreira, 1999; Sass et al., 2010). The finding by Cutting & Ferreira (1999) is particularly interesting, because they show that even distractors that do not relate to the intended meaning of the target picture can facilitate naming. In their experiment, participants saw a picture of a play ball while words such as dance (associative) or formal (coordinate) were presented simultaneously (Cutting & Ferreira, 1999). Both distractors refer to an alternative reading of the target word (ball in the sense of a dance event), which could lead to interference in this context. Nevertheless, the picture was named faster with these distractors than in a control condition with unrelated words (Cutting & Ferreira, 1999). This suggests that even competing meaning activations, if they are semantically organized, do not necessarily interfere but can, under certain conditions, have a facilitative effect. The authors explained the facilitation effect for associative distractors by suggesting that associative terms are not interconnected within the lemma system but rather have activating links at the word-form level (Cutting & Ferreira, 1999). This suggests that semantic effect depends on the type of semantic relationship between distractor and target, for example, whether it is categorical, associative, coordinate, semantically related or unrelated. The findings also support the two-stage model by Schriefers et al. (1990), according to which semantic effects arise at different processing levels. Interference occurs at the level of lemma selection, while facilitation occurs at the word-form level (Schriefers et al., 1990)[17]. When the distractor is presented early enough its lexical activation remains below the threshold (Schriefers et al., 1990; Levelt et al., 1999; Finkbeiner & Caramazza, 2006a). In this case, it can facilitate access to the target concept through its conceptual connection without triggering lexical competition (Levelt et

[17] "The first stage, lexical selection, delivers the information about lexical items needed to construct the functional level representation. The second stage, retrieval of wordforms, delivers the information needed for the construction of the positional level representation" (Schriefers et al., 1990: 86).

al., 1999). For instance, the word *donkey* used as a distractor for a picture of a *horse* activates the concept *horse* at the conceptual level. However, it does not receive enough lexical activation to compete with *horse* during lemma selection. Instead, this pre-activation makes it easier to retrieve the corresponding lemma, thereby speeding up the selection process, which is known as the facilitation effect (Schriefers et al., 1990). In the current meta-analysis, no facilitation effect was observed. In contrast, when the distractor and the target picture are presented simultaneously, an interference effect is typically observed (Glaser & Düngelhoff, 1984; Navarrete & Costa, 2005; Geng et al., 2013; Jescheniak et al., 2020). Both the distractor and the target activate related concepts and their corresponding lexical entries at the same time. As a result, the lexical representation of the distractor may become sufficiently activated to compete with the target lemma (Schriefers et al., 1990, Levelt, 1989, Levelt et al., 1999). This lexical competition slows down the selection of the target word, leading to longer response latencies. Notably, Sailor et al. (2009) reported both facilitation and interference effects at SOA of 0 msec, highlighting that different processing dynamics may occur event at the same timing. Crucially, the result of the study indicate that the type of the distractor plays a major role. In Sailor et al. (2009) associative distractors (*carrot*) facilitated naming of the target *rabbit*, whereas coordinate distractors (*chipmunk*) led to interference. Despite mixed findings in the literature, the results of the current meta-analysis were in line with the hypothesis, showing that word distractors produced significant semantic interference effects in picture naming tasks.

5.1.2 The influence of Stimulus Onset Asynchrony (SOA) in PWI studies

Although the subgroup analysis by the SOA did not reveal statistically significant differences between conditions, a closer look at the individual effect sizes suggest some meaningful patterns. In the present meta-analysis, the most robust and reliable effect was found at SOA of 0 msec ($g = 0.29$, $k = 25$), where the distractor and the target are presented simultaneously. This aligns with previous findings, which found that interference is most likely when the distractor is temporarily aligned with the target (Feyereisen et al., 1998; Cai et al., 2020; Hutson & Damian, 2014). The largest effect size in the present meta-analysis was observed at the SOA of +100 msec ($g = 0.38$). However, given the small number of studies ($k = 4$) and the very wide confidence interval ([-1.33; 2.08]), this result should be interpreted with caution. In the present meta-analysis, the effect was non-significant at earlier SOAs. This pattern aligns with the idea that distractors presented too early might already be processed or inhibited by the time the target appears, which typically occurs around 200 to 277 msec after picture onset (Indefrey & Levelt, 2004). This is consistent with earlier findings by Marslen-Wilson (1987), who reported average selection times of approximately 200 msec for spoken word recognition, based on acoustic input. Therefore, when interference is observed as at simultaneous or near-simultaneous SOAs, an additional question arises regarding the nature of the semantic relationship between the target and distractor, more precisely whether they are semantically, categorically or associatively related. Although this issue is not the central focus of the present meta-analysis, it is nonetheless worth briefly mentioning this interesting aspect based on previous findings. A further, closely related aspect that also lies beyond the main scope of this meta-analysis is whether semantic interference is modulated by the degree of semantically similarity (Vigliocco et al., 2004). This refers to the idea that interference might increase gradually with increasing semantic relatedness between target and distractor.

5.1.3 The Semantic gradient

Hutson & Damian (2014) replicated the studies by Vigliocco et al. (2004) and Mahon et al. (2007) to examine how exactly the degree of semantic relatedness between a target picture and its distractor word influences interference. Vigliocco et al. (2004) provided empirical support for graded semantic effects, demonstrating that not only relatedness but also its strength affects reaction times. In contrast, Mahone et al. (2007) argued that category-related interference (strawberry – lemon – lobster) arises from response-related mechanisms rather than semantic similarity per se, as distractors may share general features like “red” or “edible”. Notable, Vigliocco et al. (2004) remained neutral on the competition debate, though their findings have been used to support the idea that stronger similarity leads to greater interference via increased activation at both conceptual and lexical levels. However, Mahon et al. (2007) observed interference even for distantly related distractors, while closely related ones led to facilitation, a pattern not commonly predicted by theoretical models of lexical access. By taking a closer look at the SOA factor, which was manipulated in all studies, it becomes clear why the studies yielded different results. Hutson and Damian (2014) used a SOA of 0 msec, Vigliocco et al. (2004) used a SOA of -150 msec and Mahon et al. (2007) tested a range of SOAs up to +800 msec. This suggests that the emerge of semantic effects may depend more on timing than on the type of the distractor. Hutson and Damian (2014) speculate that the degree of semantic relatedness may only influence processing when distractors are presented early (negative SOA), not simultaneously. But current models, such as WEAVER++ (Levelt et al., 1999) and the REH (Mahon et al., 2007 Janssen et al., 2008; Dhooge & Hartsuiker, 2010) do not provide a clear prediction about such an interaction between SOA and semantic distance. Vromans & Jongman (2018) reported that according to Indefrey & Levelt (2004) a picture naming trial proceeds from conceptual preparation to articulation in about 600 msec, emphasizing the temporal sensitivity of lexical access.

5.1.4 Familiarization vs. no Familiarization in PWI studies

One of the inclusion criteria for this meta-analysis was to consider only studies that included a familiarization phase, to avoid inconsistencies. Gauvin et al. (2018) showed that prior familiarization with the stimulus increases the likelihood of observing semantic interference. Gauvin et al. (2018) aimed to systematically investigate whether omitting the familiarization phase influences the semantic interference effect and whether this effect truly depends on participants’ prior knowledge of the stimulus. Surprisingly, without familiarization even semantically related distractors fail to produce interference (Gauvin et al., 2018). However, in trials without familiarization not only was the absence of semantic interference observed, but error rates also increased with semantically related distractors. Gauvin et al. (2018) study highlights that the familiarization phase plays a crucial role in the occurrence of semantic interference within the PWI paradigm. In the literature, only the WEAVER++ model by Levelt et al. (1999) explicitly takes the familiarization phase into account, stating that “as long as these distractors are not part of the response set, they should facilitate naming relative to unrelated distractors” (Levelt et al., 1999: 11). According to the REH familiarization should not influence the presence or absence of the effect. One possible explanation is that familiarization increases participants’ awareness of the task’s semantic structure, drawing attention to the distractors and the instruction to name the target. This mechanism resembles the paradox, where trying not to think about something makes it even harder to suppress that specific thought. Future research could assess during familiarization and the main task whether this effect remains stable or change over time.

5.1.5 Time pressure vs. no time pressure in PWI studies

Beside the factor of attention, time pressure is another condition that influences the presence of a semantic interference effect which is demonstrated in Cai et al. (2020). They demonstrated that under time pressure, no semantic interference was found, but interference occurred without time pressure (Cai et al., 2020). Under time pressure, more attention was directed toward the target picture, while the processing of irrelevant distractors was reduced (Cai et al., 2020). However, the error rate was higher in the time pressure condition than without time pressure (Cai et al., 2020). A similar conclusion was drawn by Llyed-Jones and Nettlemill (2007) who focused on error patterns under time pressure rather than semantic interference in picture naming tasks. They found that visual-semantic errors, for example, naming zebra as “giraffe”, increased for living objects, especially animals, due to their visual complexity (Lyled-Jones & Nettlemill, 2007). In contrast, pure semantic errors, like naming a nut as a bolt (Lloyed-Jones & Nettlemill, 2007: 816), were more common for non-living objects and linked to factors like imageability and age of acquisition (Lyled-Jones & Nettlemill, 2007). These findings support the competitive lexical view by showing that error patterns reflect lexical competition. The study by Lloyed-Jones & Nettlemill (2007) complements the error pattern in present meta-analysis by demonstrating the link between processing constraints and semantic interference. It shows that different cognitive factors, such as similarity and SOA influence the type and frequency of errors under increased lexical access. The findings in Cai et al. (2018) are particularly interesting because in classic picture naming studies a single trial[18] lasts approximately 800 msec, after which the next trial begins (Indefrey & Levelt, 2004; Indefrey, 2011). Notable, such effects were absent without time pressure and demonstrates that attention plays a significant role in picture naming tasks.

5.1.6 Factor Age in PWI studies

With regard to the factor of age, Feyereisen et al. (1998) showed that semantic interference was also observed in both younger and older participants. Although there were overall differences in magnitude, such as longer reaction times in older adults, the pattern of interference was similar across both age groups. The study conducted by Hanauer & Brooks (2005) examines how the ability to suppress linguistic distraction develops during childhood, focusing on semantic interference in the PWI paradigm. The results show that with age, children become better at forming a mental response set and managing interference more effectively (Hanauer & Brooks, 2005). Adults can suppress irrelevant auditory input more efficiently, leading to interference only under specific timing conditions (Hanauer & Brooks, 2005). However, such an interpretation cannot be applied for the non-competitive or REH, because they argue that the time in which a specific word is selected does not depend on how strongly other words are activated at the same time (Vromans & Jongman, 2018). Therefore, there is no need to supress other words to select the correct one (Vromans & Jongman, 2018).

[18] a single trial in picture naming studies typically ranges from the presentation of the stimulus presentation to vocal response (Indefrey & Levelt, 2004).

5.1.7 Interim Summary PWI

Taken together, in the current meta-analysis word distractors showed significant interference effects. The findings on PWI paradigm highlight how semantic interference is shaped by multiple factors, including the timing of distractor presentation (SOA), the type of semantic relationship between target and distractor and attentional demands. According to the present meta-analysis semantic interference typically occurs when semantically related distractors are presented simultaneously with or shortly after the target picture, suggesting that lemma selection takes place during this period and is susceptible to lexical competition (Indefrey & Levelt, 2004). Facilitation, on the other hand, emerges under specific conditions such as long SOAs, masked distractors or associative relationships (Finkbeiner & Caramazza, 2006; Sailor et al., 2009; Cutting & Ferreira, 1999, Sass et al. 2010). These effects could not be observed in the meta-analysis. Previous studies showed that the strength of interference also depends on the degree of semantic overlap between distractor and target, although findings remain mixed regarding whether closely or distantly related distractors produce stronger effects (Vigliocco et al., 2004, Mahon et al., 2007; Hutson & Damian, 2014). Surprisingly, familiarization with target pictures, a factor previously given little attention in the literature, appears to play a crucial role in the emergence of semantic interference effects (Gauvin et al., 2018). In addition, attentional focus, modulated by time pressure (Cai et al., 2020), further influences interference effects, while age seems to have only minor impact (Feyereisen et al., 1998). Having summarized the key findings from the PWI paradigm, the focus now shifts to PSI studies, which offer insights into how sound distractors may influence speech production.

5.2 Picture-Sound Interference

In the present meta-analysis, sound distractor showed a positive but not-significant effect. Although an interference effect was expected based on previous findings, it was not statistically confirmed. This could be due to the small number of including studies ($k = 4$) as well as the strict inclusion criteria applied. Nevertheless, in other PSI studies (Schriefers et al., 1990; Jescheniak et al., 2020; Hanauer & Brooks, 2005; De Zubicaray and McMahon, 2009; Mädebach et al., 2017, 2018) significant semantic interference effects were observed. The reason why this effect was not observed in the present meta-analysis lies in the crucial factor, namely the selected SOA. As outlined in the methodology, only studies with SOAs of -200 msec, -100 msec, 0 msec and +100 msec were included in order to ensure comparability with other distractor types. Consequently, studies with other SOAs were excluded from the analysis, which may have contributed to the absence of a significant effect. However, Schriefers et al. (1990) observed a semantic interference effect when the distractor sounds were presented early at a SOA of – 150 msec, but not when they were presented simultaneously or later at a SOA of +150 msec. In contrast, a facilitation effect was found at SOAs of 0 msec and +150 msec (Schriefers et al., 1990). Interestingly, while distractor sounds led to facilitation effect at SOAs of -150 msec and 0 msec, distractor words produced a semantic interference effect at the very same SOAs (Damian & Martin, 1999). Damian and Martin (1999) explain this pattern by suggesting that distractor presented before the target are fully processed and may facilitate target naming by pre-activation related conceptual or lexical information. In contrast, when the distractor appears shortly after the target, only partial processing occurs, which may disrupt lexical selection and lead to interference due to incomplete or competing activation (Damian & Martin, 1999). For a long time, research on lexical access in speech production was dominated by studies using the PWI paradigm, where visual distractor words are presented alongside target pictures. This approach yielded important insights into the timing and mechanism of conceptual and lexical process. However, it was not until the study by Schriefers, Meyer & Levelt (1990) that sound distractors were first introduced into picture naming experiments, although their main focus remained on visual stimuli. In their study, sound distractors were presented to ensure that participants would generate phonological rather than graphemic representations of the interfering stimuli (Schriefers et al., 1990). This methodological choice was crucial for testing the seriality assumption of lexical access, according to which semantic and phonological stages occur independently and sequentially (Schriefers et al., 1990). Beyond this theoretical interest, the use of sound distractors also opened the possibility to examine whether semantic interference effects emerge only with written words or also with other modalities, such as sound and picture distractors. Hantsch, Jescheniak and Schriefers (2009) systematically compared visual and sound distractors and the proportion of response congruent trials, using basic-level distractors (“fish”) during subordinate-level picture naming (“carp”). Their result demonstrated the sound distractors consistently caused semantic interference regardless of response congruency, whereas word distractors led to facilitation effects only when the proportion of the response-congruent trails was high (Hantsch et al., 2009). Their findings show that semantic facilitation should not be used as evidence against lexical selection by competition, but rather highlight the importance of experimental design features, such as distractor modality or response congruency, that may modulate the observed semantic effects (Hantsch et al., 2009). However, these findings suggest that semantic interference is not restricted to word distractors but also occurs with non-verbal. On the other hand, REH propose that interference results from distractor words entering the articulatory buffer and that only verbal stimuli have privileged access to this buffer (Mahon et al., 2007, Spalek et al., 2013). Furthermore, in the study by Hantsch, Jescheniak and Mädebach (2012), a parallel to classic PWI-studies can be observed, in which the relationship between target and distractor was systematically manipulated. Hantsch et al. (2012) presented participants with a picture of a poodle while the distractor word “poodle” (a subordinate-level term) was played, although participants were instructed to respond with the basic-level label “dog”. Hence, target and distractor were not semantically related in the typical sense of lexical competitors, but rather hierarchically related, referring to the same object at different levels of abstraction. The findings by Hantsch et al. (2012) suggest that the absence of semantic interference in subordinate-level picture naming with basic-level distractors can be attributed to a response congruence mechanism, which facilitates target selection and operates alongside lexical competition. Interestingly, similar patterns have been reported in classic PWI studies, where facilitation effects occurred when the relationship between target and distractor was manipulated, such as with associative distractors (Cutting & Ferreira, 1999) or masked distractors (Finkbeiner & Caramazza, 2006). These findings suggest that facilitation may occur whenever distractors help to activate the target concept but do not strongly compete at the lexical level. Mädebach et al. (2017) were motivated to challenge the non-competitive accounts and assumed following two hypotheses. First, if semantic interference, is specific to distractor words, it should not occur when distractor sounds are used (Mädebach et al., 2017). Second, if semantic interference is not limited to distractor words, as proposed by the competitive selection account, then semantic interference might also arise with sounds (Mädebach et al., 2017). They found out that identifying sounds takes longer than identifying words or pictures (Mädebach et al., 2017). At an early or negative SOA from a range of -800 msec, -500 msec and -200 msec, they observed in all SOA stages interference, but was weakest at -500 msec and strongest at -200 msec (Mädebach et al., 2017). Similar to findings from PWI studies, the authors showed that congruent sounds facilitated naming responses compared to unrelated sounds, whereas semantically related sounds caused interference (Mädebach et al., 2017). They explain the observed facilitation effect as follows: "[…] the processing of sounds and pictures activates a shared semantic network, which in turn pre-activates representations in the lexical network involved in word production (Mädebach et al., 2017: 1639). According to interference, they acknowledged that the very weak effect at -500 msec might be due to the fact that interference effects are not always linearly related to SOA (Mädebach et al., 2017). In their second Experiment, the results revealed that the semantic interference effect was significant at SOAs of -200 msec and -100 msec, but not at 0 msec (Mädebach et al., 2017). Nonetheless, the findings suggest that the interference effect from sound distractors may emerge in a slightly earlier time window compared to word distractors. The question that arises for the researchers is how the findings of their study can be reconciled with a non-competitive account. For example, according to the REH, the distractor, in this scenario a sound, would need to gain access to the output buffer to interfere. But not only proponents of the non-competitive view, but also Mädebach et al. (2017) argue that this is highly unlikely. Just because one perceives environmental sounds does not mean they immediately have the corresponding word ready for articulation, especially if they have no intention of using that word in context. This would imply that speakers are prompted to form lexical representations of environmental sounds even they are not actually speaking.

5.2.1 Interim Summary PSI

Taken together, findings from PSI studies indicate that semantic interference is not restricted to visual words but can also arise from sound distractors, particularly at early or negative SOAs. While the present meta-analysis revealed a positive but non-significant overall effect for sound distractors (k =4), several experimental studies (Schriefers et al., 1990; Hanauer & Brooks, 2005; De Zubicaray & McMahon; Mädebach et al., 2017, 2018,) reported reliable semantic interference effects in picture naming tasks, but at different SOAs. In contrast, no interference was found at SOA of 0 msec, so far in the literature, which may be due to the temporal dynamics of auditory processing. These effects suggest that semantic interference form environmental sounds emerges when distractors are processed early enough to overlap with lexical selection. Facilitation effects were also observed for congruent sounds, indicating that semantic activation can either support or hinder target selection depending on the relationship between distractor and target (Mädebach et al., 2017). The PSI paradigm thus represents a valuable and novel addition to the relatively small set of experimental paradigms available for investigating word and speech production.

5.3 Picture-Picture Interference

In the present meta-analysis, no significant effect was found in PPI studies. This is not surprising, as the literature often reports that in most PPI studies no effect was observed (Damian & Bowers, 2003; Geng et al., 2013), despite their semantic relatedness. The only findings of semantic interference include a cue during the task (Matushanskaya et al., 2016). Some studies even reported an effect under negative SOA conditions, for instance in Matushanskaya et al. (2016) used a SOA of -67 msec or a cue was introduced after both pictures had been presented simultaneously and became visible only after a certain delay. The studies by Damian & Bowers (2003), Navarrete & Costa (2005), Geng et al. (2013), and Matushanskaya et al. (2020), were all including in the present meta-analysis. These studies investigate whether and under which conditions semantic interference occurs with picture distractors in picture naming tasks and on which processing level effect is located. Damian & Bowers (2003) showed that semantic interference only occurred when the distractor was presented as a word and simultaneously with the target picture, but crucially no interference was found with picture distractors. The authors (2003) concluded that the absence of a semantic interference effect was taken as evidence that such interference in PWI tasks is specific to speech production, occurring only when lexical retrieval of the target stimulus is required. Moreover, it was shown that directing visual attention to the target image can prevent interference from distractors. Fias (1995, as cited in Damian & Bowers, 2003) demonstrated that semantic interference with picture distractors is possible when participants were cued after both pictures had been presented simultaneously to indicate which picture should be named. Interference only occurred when the cue was delayed (+500, +2000 ms) (Damian & Bowers, 2003). However, when the target was marked by colour, the effect disappeared, indicating that clear target identification can prevent semantic interference (Damian & Bowers, 2003). This experiment was replicated by Matushanskaya et al. (2016) and found no semantic interference effect either. Additionally, Matushanskaya et al. (2020) also found that semantic interference with pictures only arises when the distractor is sufficiently processed. In their experiment, attention was specifically directed towards the target by an invalid cue and only under these conditions did interference occur. Navarrete & Costa (2005) examined both semantic and phonological relationships between distractor and target pictures. In their experiment, no semantic interference effects were found at a SOA of 0 msec, but phonological facilitation effect was observed (Navarrete & Costa, 2005). Distractor pictures that were phonologically similar to the target picture led to faster naming times. These findings were also observed in PSI studies (Mädebach et al., 2017, 2018). Geng et al. (2013) obtained similar results as in PWI studies (Cutting & Ferreira, 1999), where facilitation effect was found when the target and distractor pictures were associatively rather than categorically related. Gang et al. (2013) discuss that both competitive and non-competitive theories struggle to account for the coexistence of semantic facilitation and interference effects in PWI paradigms. Geng et al. (2013) demonstrated that both pictures and words can cause interference by activation lexical entries, even though they rely on different processing routes. Words access lexical representations directly, whereas pictures are first processed on a conceptual level and only then is the corresponding lexical entry retrieved (Roelofs, 1992; Gang et al., 2013). However, semantic interference only occurs when the picture distractor is sufficiently processed, via attentional focus, such a cue. This result supports the *"swinging network model*" by Abdel Rahman & Melinger (2009) assumption that conceptual facilitation and lexical competition influence each other. "The swinging lexical network explains the semantic effects observed in PWI and PPI as a result of trade-offs between lexical competition and conceptual facilitation" (Gang et al., 2013: 270). Semantic relatedness can lead to conceptual facilitation as well as lexical competition (Abdel Rahman & Melinger, 2009). Whether interference or facilitation is ultimately observed depends on the interaction of both processes (Abdel Rahman & Melinger, 2009).

5.3.1 Interim Summary: Picture-Picture Interference

Taken together, the findings form PPI suggest that semantic interference is generally absent unless specific conditions are met, such as the use of attentional cues or negative SOAs (Fias, 1995; Matushanskaya et al., 2026). The present meta-analysis found no significant semantic effect for picture distractor in classic picture naming studies, which aligns with previous research showing that such effects only occur when picture distractors are processed with given cues. While phonological facilitation has been observed (Navarrete & Costa, 2005), semantic interference appears to require attention and high levels of lexical activation. These results support models like the *Swinging Lexical Network* (Abdel Rahman & Melinger, 2009), which assumes that both conceptual facilitation and lexical competition determines the outcome of interference effects. To sum up, Mädebach et al. (2017) summarize the core problem effectively:

> "Neither competitive nor noncompetitive language production models provide a ready explanation why neither semantic interference (as predicted by competitive models) nor facilitation (as predicted by noncompetitive models) is observed with distractor pictures, especially in light of evidence showing that distractor pictures do induce phonological effects" (Mädebach et al., 2017: 1642).

5.4 General Discussion

The following section summarizes and compares the semantic interference effects across the different types of distractors by focusing on commonalities and differences in effect direction, SOA and underlying mechanism of lexical access, which are the main focus of the present master's thesis. Based on the results of the present meta-analysis, a significant semantic interference effect was found only for word distractors. A positive but non-significant effect was observed for sound distractors, while no effect was found for picture distractors. The strongest and most consistent semantic interference effect was observed for word distractors, particularly at SOAs of 0 msec and +100 msec, aligning with the critical time window of lexical selection (Indefrey & Levelt, 2004). This supports the view that word distractors activate competing lexical entries directly and interfere most strongly when their processing temporarily overlaps with target name retrieval. In addition, the highest number of errors was also found in studies with word distractors, suggesting that the strongest interference effects are accompanied by the highest rate of speaker errors. The results in sound distractors showed a positive but non-significant interference effect at a SOA of -200 msec, suggesting that early distractor processing can also lead to interference when sufficiently activated. With regard to error rates, the fewest mistakes were made in the semantically related condition, suggesting that speakers are not disrupted by sounds that are semantically related to the target picture. However, as mentioned before, these findings regarding sound and picture distractor should be interpreted with caution, as they are based on only four studies each, in contrast to the substantially larger number of PWI studies included in the analysis. These results raise the question of how well existing theoretical models explain the observed effects, particularly in light of the differences between competitive and non-competitive accounts of lexical access.

To sum up, the results of the present meta-analysis do not provide support for either the competing or the non-competitive theoretical accounts. Rather, the observed patterns of semantic interference partially align with the aspects of all three theoretical models, but none is fully supported. The following table summarizes the findings for each distractor type and indicates to what extent they are consistent with the predications of the competitive view, non-competitive view and the REH.

Table 6: Theoretical Interpretation of Interference Effects by Distractor Type

Distractor Type	**presence of semantic interference effect**	**Interpretation for theoretical accounts**
Word	yes	compatible with bot Competitive and REH, but not by non-competitive view
Sound	no	partially compatible with competitive view, consistent with non-competitive view, problematic with REH
Picture	no	supports REH and non-competitive, contradicts with competitive view

5.4.1 The Locus of the Semantic Interference Effect

One of the central questions concerns the level at which semantic interference and facilitation effect arise. It is debated whether these effects arise during the conceptual stage (Roelofs, 1992), the lexical stage (Levelt et al., 1999) or at a post-lexical level, leading to articulation (Finkbeiner & Caramazza, 2006b; Mahon et al., 2007). At the conceptual level, speech production begins with the perception or mental representation of an object to be named. As outlined by Levelt et al. (1999), this initial stage involves the activation of a conceptual representation that provides the foundation for lexical selection. Semantic effects are widely believed to originate at this level, but interference arises only when lexical selection is required (Schriefers et al., 1990; Damian & Bowers, 2003; Jescheniak et al., 2020). According to this view, distractors co-activate semantically related concepts, yet interference occurs only if the distractor also reaches a level of activation sufficient to compete at the lexical level. PPI studies often assume that semantic interference originates at the conceptual level, since both the target and distractor are visual stimuli that may not directly activate lexical representations (Sailor et al., 2009). Accordingly, any observed interference in PPI paradigms is thought to occur prior to lexical access (Glaser & Glaser, 1989; Mahon et al., 2007). Support for this distinction also comes from studies showing that semantically related distractors produce facilitation in non-lexical tasks, such size judgement (Jescheniak et al., 2020) but interference in naming tasks, which require lexical access (Jescheniak et al., 2020). These findings suggest that conceptual activation is a necessary precondition for semantic effects, but that interference depends on competition during lexical access. In Schriefers et al. (1990) the authors investigated the locus of the semantic interference effect. To test this, they replaced the classic naming task with a recognition task in which participants indicated via button press whether a picture had been shown earlier. In one of their experiments the semantic interference effect was previously observed in naming tasks (Schriefers et al., 1990) but disappeared under these conditions. These findings suggest that distractor interfere with lexical retrieval during naming, but not with recognition. In PPI paradigms, distractors may not trigger lexical access, especially if they are task-irrelevant or not deeply processed (Mahon et al., 2007). A central argument of the REH is that words as distractors in picture naming studies initiate articulatory motors processes early on, while pictures as distractors must be first processed conceptually (Mahon et al., 2007). As Mahon et al. (2007: 526) put it "[…] when the distracting stimulus is a picture, the distractor does not have a privileged relationship to articulatory processes". For better understanding, a picture can have more than one definition, for example a picture of a "dog" could be labelled as "puppy" or "pet", depending on the speaker's familiarity, knowledge or interpretation. In contrast, a written word presented on a screen clearly demands reading that specific word. The same applies to distractors sounds, for example, hearing a neighing sound (Mädebach et al., 2017), it is immediately clear that it comes from a horse. Unlike, pictures, which may allow for multiple naming options.

Mädebach et al. (2011) referred to a study by Janssen et al. (2008), who reported a semantic interference in a delayed naming task and argued for a post-lexical level. In Janssen et al.'s (2008) experiment, participants first viewed a picture and after 1000 msec named either the picture or the word depending on its colour. Mädebach et al. (2011) replicated the study by using the same materials[19] but found no interference effect. They argue that the task-switching introduces additional cognitive demand, such as switching between naming and reading depending on the word colour (Mädebach et al., 2011) and suggested that the finding of a effect reported in Janssen et al. (2008) may have occurred by chance. While their findings could support the REH if the relevant conditions were clearly defined Mädebach et al. (2011) argue that in the absence of such clarity, the study should not be taken as evidence for a post-lexical locus of interference.

5.4.2 Challenges for the Competitive View and Response Exclusion Hypothesis

The competitive view is widely accepted by researchers in the field of word production. Nonetheless, several studies have challenged the competitive model by proposing specific modifications. The most well-known is the REH, which has been tested in serval studies by varying the type of stimuli. The modification described below were already mentioned in the Introduction. In this section, they will be explained in more detail to clarify the discrepancies between different approaches to lexical access.

Finkbeiner & Caramazza (2006b) conclude that the more relevant a semantically related distractor is, the more slowly it can be excluded from the articulatory buffer. Notably in their study (2006b) they used masked distractor words, which led to facilitation, while interference was observed with unmasked distractors. They based their assumption on findings by Miozzo

[19] Mädebach et al. (2011) used different colours to indicate task type (black and dark blue vs. blue and red), they note that these were identical to those used in Janssen et al.'s, (2008) Experiment 2. Thus it is unlikely that this difference explains the failure to replicate the semantic interference effect (Mädebach et al., 2011: 532).

& Caramazza (2003), who showed that low-frequency distractors cause more interference than high-frequency ones, which contradicts the REH. Both studies indicate that semantic interference is primarily driven by how strongly the distractor is activated at the phonological level, rather than by semantic similarity alone (Finkbeiner & Caramazza, 2006b). Mulatti and Coltheart (2011) critically examined the REH, which proposes that in PWI tasks, distractor words automatically enter a *single-channel output buffer* (Mulatti & Coltheart, 2011: 363) and must be removed before the target name can be articulated. According to the REH, interference occurs when the target response is ready but must wait for the distractor to be cleared (Mulatti & Coltheart, 2011). This delay depends on how quickly the distractor is processed and how challenging it is to reject it, based on its relevance to the target. On the other hand, the REH can account for some findings, such as additive effects of distractor frequency and semantic interference (Mulatti & Coltheart, 2011). But it fails to explain others, notably the consistent effect of picture name frequency (Mulatti & Coltheart, 2011). This mismatch is especially evident in data from Miozzo & Caramazza (2003), who showed that high-frequency distractors caused less interference, a result that does not align with the REH.

In response, Mahon et al. (2012) expressed concern about how the REH was represented by Mulatti and Coltheart (2011). Instead, Mahon et al. (2012) emphasize that the timing and interaction between distractor processing and target word preparation are critical. They propose that the output buffer, which can only hold one response at a time, may not begin processing the distractor immediately. It is possible, for example, that buffer clearing only starts once the target representation is ready, or that the system receives advance signals about the target, allowing it to prepare. In such cases, effects of picture name frequency would still be observed, which is entirely consistent with the REH.

Interestingly, in the study by Miozzo & Caramazza (2003) categorically related distractors cause interference, but the same distractors cause facilitation when they were masked. The REH explains this effect as a consequence of process within the response buffer. Therefore, unmasked distractors lead to interference because they need to be actively removed before the target response can be articulated. However, semantic facilitation with masked distractors is "too weak to engage the response selection process, but it is still strong enough to prime the target representation via overlap in their respective semantic properties" (Spalek 2013: 604). This interpretation is further supported by Damian & Spalek (2014) who emphasize the role of conscious perception and activation strength, which the REH does not account for. Damian & Spalek (2014) argue that the visibility of a distractor alone does not determine the direction of the effect. Although the ability to consciously perceive masked distractors varied greatly between participants, the overall pattern revealed weak semantic facilitation under masking condition (Damian & Spalek, 2014).

In addition, Mahon et al. (2007) also examined semantic distance effects in PWI tasks, assuming that the semantic effect of a distractor reflects both facilitation at the lexical-conceptual level and interference at the post-lexical level. While semantically closer distractors should enhance target word production more than distant ones, both types of distractors are according to the REH equally response relevant. Their experimental results confirmed this prediction, showing strong interference from weakly related distractors but little or no interference from strongly related ones (Mahon et al. 2007). In contrast, Fieder et al. (2019) challenges this core assumption by showing in a speed picture naming task that, even without distractor words, naming was slower and less accurate when target words had many closely related semantic neighbours. Crucially, the interference was specifically driven by close semantic neighbours, whereas distant semantic neighbours had no effect.

Finally, to illustrate how the ongoing debate between proponents of competitive and non-competitive accounts, such as the REH, can unfold in concrete empirical finds, the following example highlights a well-known exchange between Hantsch and Mädebach (2013) and Navarrete and Mahon (2013). This will also serve as a final point in the discussion.

To begin with, Hantsch and Mädebach (2013) challenged a central assumption of the REH that semantic interference is determined by the relevance of distractors in accessing the output buffer. In their study (Hantsch & Mädebach, 2013), participants were shown a picture of a rose and a distractor word, which was either "rose" (subordinate identical) or "tulip" (subordinate alternative). Importantly, participants were instructed not to name the pictures as "rose" but instead to use the more general term "flower" (Hantsch & Mädebach, 2013 :687). However, the results showed that interference occurred only with the distractors "rose" but not with "tulip". Based on these findings, Hantsch and Mädebach (2013) argued that the REH fails to account for this and that the data are more consistent with lexical competition models like WEAVER++ (Levelt et al., 1999), which predict interference when co-activated lexical entries exceed a certain threshold.

In response, Navarrete and Mahon (2013) defended the REH and criticized the interpretation of Hantsch and Mädebach (2013). They argued that "rose" is more strongly linked to the target picture than "tulip" and this caused the stronger interference. From their perspective the findings are consistent with the REH. Moreover, Navarette and Mahon (2013) proposed that the interference observed resembles a Stroop effect in which the distractor word "rose" automatically activated it lexical representation which directly competes with the instructed response "flower" as participants were instructed to name the picture "flower" instead of "rose". This conflict delays response selection in the same way that incongruent colour words interfere with colour naming in the classic Stroop task (Navarette & Mahon, 2013).

In their rejoinder, Mädebach and Hantsch (2013) defended their interpretation of, emphasizing again, that their findings support competition-based models and argued that only lexical entries with strong activation, like "rose" lead to interference while semantically related but less dominant, like "tulip" do not. According to Mädebach and Hantsch (2013) the REH fails to explain their findings sufficiently.

6. FUTURE RESEARCH

Despite the valuable insights gained form this meta-analysis, several questions remain unanswered. One key limitation lies in the unequal distribution of studies across distractor types and SOA conditions. Future research should aim to include a greater number of studies with non-verbal distractors, such as sound and pictures, that meet standard methodological criteria. In addition, to enable systematic and meaningful comparisons across distractor types, future research should generate more studies involving these modalities are needed. Once, a more balanced dataset is available, a follow-up meta-analysis could be conducted to draw more robust conclusions about different types of distractors.

On the other hand, in light of the ongoing debate about lexical access, Spalek et al. (2013) have called for the development of new experimental paradigms beyond the classic PWI task. Supporting this idea, Wöhner et al. (2020) demonstrated that semantic interference can also arise in tasks where sounds function as targets and pictures as distractors. The results were the same as in classic PWI tasks (Wöhner et al., 2020). Such alternatives designs may offer new perspectives on how semantic interference operates across different modalities and stimulus types.

Moreover, researchers should be cautions in interpreting stronger interference effects at longer reaction times as clear evidence of inhibition (Cutting & Ferreira, 1999; Fuhrmeister & Bürki, 2022). As shown in Fuhrmeister and Bürki (2022) such effects can result from statistical properties of reaction time distributions, rather than genuine inhibitory processes. This calls for more precise statistical modelling and a critical examination of the assumptions underlying interference interpretations.

Furthermore, future studies could also benefit from neurocognitive methods such as EEG or fMRI to explore the temporal dynamics and neural correlates of semantic interference effect (De Zubicaray & McMahon, 2009). In their fMRI study, De Zubicaray and McMahon (2009) revealed that increased activation in the left inferior frontal gyrus (LIFG) and temporoparietal regions (TP) when participants named pictures in the presence of semantically related sound distractors. Such investigations could help determine whether different distractor types share or distinct processing mechanisms. In addition, brain imaging may help identify the neural locus of semantic interference by revealing which brain areas are active during interference.

Finally, Abdel Rahman and Melinger (2009) propose the *Swinging Lexical Network*, a framework that does not introduce a new mechanism but integrates and extends principles from existing competitive models. Crucially, it accounts for both semantic interference and facilitation in picture naming by assuming that sematic context simultaneously triggers two processes (Sailor et al., 2009). First, conceptual priming, which facilitates naming and lexical competition, which leads to interference (Abdel Rahman & Melinger, 2009). Whether interference or facilitation emerges depends on the structure and strength of activation within the semantic network. For example, if target and distractor are associatively related than activation may result in facilitation (Cutting & Ferreira, 1999; Sass et al., 2010). If target and distractor are semantically related the links in the semantic network are stronger activation and activation leads to interference (Schriefers et al., 1990; Levelt et al., 1999; Damian & Spalek, 2014). This model allows to account for both interference and facilitation effects unlike other competitive accounts. Importantly, the authors clearly distance themselves from the REH which assumes interference at post-lexical level. Instead, they argue that interference arises during lexical selection when semantically related lexical items are co-activated and compete for access (Abdel Rahman & Melinger, 2009).

7. CONCLUSION

This meta-analysis investigated whether semantic interference in picture naming tasks depends on the type of distractor, focusing on semantically related and unrelated distractors such as words, sounds and pictures. The results support previous findings in the literature, particularly in conditions involving word distractors and support the view that lexical access is sensitive to different types of distractors and stimuli. The clearest and most consistent interference effects were found when semantically related words were presented simultaneously with the target pictures. These findings are compatible with competitive models of lexical selection, such as the WEAVER++ model by Levelt et al. (1999). In contrast, sound distractors produced a positive, but a non-significant effect, and picture distractors produced no interference, suggesting that not all distractors engage the same processing mechanisms. Importantly, while the overall effect size across all included studies was moderate ($g = 0.27$), subgroup analyses revealed clear differences between distractor types. Word distractors consistently caused both slower response latencies and higher error rates when semantically related. Pictures distractors, on the other hand, had negligible effects and sound distractors even showed a small negative error difference, possibly due to reduced processing overlap with the target. From a theoretical perspective, these findings do not offer support for one lexical access model over another. Rather, they suggest that semantic interference is best understood as a multifactorial phenomenon, arising through different mechanisms depending on distractor type and timing. Nevertheless, the results should also be interpreted carefully due to the less numbers of naming studies with sound and picture distractors. Although several PSI and PPI studies were identified during the literature search, the often had to be excluded due to methodological inclusion criteria. As result, the estimates for PSI and PPI conditions are based in fewer data points and may be less reliable or generalizable. To enable future meta-analyses with broader scope and better comparability, it would be important to conduct more naming studies using sound or picture distractors that closely follow the methodological standards of classical PWI designs.

To sum up, this master's thesis conducted a meta-analysis to contribute to the ongoing debate about the mechanism underlying lexical access and semantic interference in word production. By systematically comparing distractor types and SOA conditions across studies, the present findings align with previous literature and clarify how different theoretical approaches account for the semantic interference effect. Despite these limitations, this meta-analysis represents the first systematic comparison of three different types of distractors conducted within the framework of classical PWI paradigms, according to the available research. It thus provides a novel contribution to the empirical and theoretical understanding of semantic interference in speech production.

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9. APPENDIX

9.1 Excerpt from the dataset

The dataset was created in Excel and includes all 21 studies used in the analysis, the data extracted from each study and the effect sizes computed in R.

StudyID	year	author	title	n	mr	sdr	semr	fqr	mu	sdu	semu	fqu	soa	distractor	t	df	r	sd_pooled	d	g
Study1	2017	Mädebach, W	Neighing, Bark	24	684	63,7	13	2.2	656	63,7	13	3.5	-200	s	3.43	35	0,50157296	63,7	0,43956044	0,42440318
Study1	2017	Mädebach, W	Neighing, Bark	24	712	73,49	15	2.7	685	68,59	14	2.3	-200	s	3.54	36	0,50814886	71,0822348	0,37984174	0,36674375
Study1	2017	Mädebach, W	Neighing, Bark	24	698	63,69	13	2.1	678	68,59	14	1.4	-100	s	2.86	25	0,49651281	66,1853617	0,30218162	0,29176157
Study1	2017	Mädebach, W	Neighing, Bark	24	687	53,89	11	2.2	679	53,89	11	1.3	0	s	1.30	33	0,22071975	53,89	0,14845055	0,14333156
Study2	1984	Glaser& Düng	The Time Cou	9	716	58,41	19,47	3.9	712	52,35	17,45	3.9	-200	w	0.153	16	0,03822205	55,4628281	0,07212038	0,064107
Study2	1984	Glaser& Düng	The Time Cou	9	750	58,41	19,47	3.9	725	52,35	17,45	3.9	-100	w	0.96	16	0,23337295	55,4628281	0,45075235	0,40066875
Study2	1984	Glaser& Düng	The Time Cou	9	794	58,41	19,47	3.9	710	52,35	17,45	3.9	0	w	3.21	16	0,62588322	55,4628281	1,51452789	1,34624701
Study2	1984	Glaser& Düng	The Time Cou	9	801	58,41	19,47	3.9	722	52,35	17,45	3.9	100	w	3.02	16	0,6025508	55,4628281	1,42437742	1,26611326
Study3	2006	Finkbeiner &	Now you see i	18	841	76	17,92	6.9	809	96	22,64	5.6	0	w	2.40	16	0,51449576	86,5794433	0,36960275	0,35200262
Study4	2011	Mädebach, O	Is There Sema	16	809	120	30	9.1	780	96	24	4.7	0	w	2.66	15	0,566142	108,664622	0,26687619	0,25231931
Study5	2009	Zubicaray & I	Auditory conte	17	935	290	70,31	2.6	914	300	72,83	3.5	0	s	2.44	16	0,5207592	295,04237	0,07117622	0,06755709
Study6	2018	Mädebach, K	Localizing sem	24	985	186,16	38	4.4	963	156,77	32	6.3	0	s	2.68	23	0,4878181	172,093548	0,12783745	0,12342926
Study7	2005	Navarrete & (	Phonological a	18	763	77	18,14	5.8	762	73	17,21	6.3	0	p	0.99	17	0,23347433	75,0266619	0,0133286	0,0126939
Study7	2005	Navarrete & (	Phonological a	18	777	71	16,74	5.8	754	58	13,67	3.2	0	w	2.76	17	0,55627075	64,826692	0,35479213	0,33789726
Study8	2013	Geng, Kirchge	The mechanis	45	693	16,32	2,43	4.0	671	16,32	2,43	4.0	0	w	7.17	44	0,73404843	16,32	1,34803922	1,3243894
Study8	2013	Geng, Kirchge	The mechanis	45	686	30,22	4,5	3.0	684	30,22	4,5	3.0	0	p	0.99	44	0,14761313	30,22	0,06618134	0,06502026
Study9	2016	Matushanska	When Sufficie	24	636	53,89	11		631	49	10		0	p	2.13	23	0,40590283	51,5030684	0,09708159	0,09373395
Study10	2005	Hanauera & E	Contributions	30	695	65,72	12		714	71,2	13		0	s	3.01	29	0,4879008	68,5148101	-0,27731231	-0,26981738
Study11	2009	Sailor, Brooks	Exploring the t	24	681	78	15,92		655	66	13,47		0	w	5.03	184	0,34768218	72,2495675	0,35986375	0,34745465
Study12	2007	Mahon, Peter	Lexical Selecti	24	745	110	22,45	2.8	728	96	19,6	2.2	0	w	2.12	23	0,40430931	103,23759	0,1646687	0,15899047
Study13	2003	Damian & Bo	Locus of sema	28	615	68	12,85	3.2	612	70	13,23	2.6	-200	w	1.10	27	0,20710527	69,007246	0,0434737	0,04220747
Study13	2003	Damian & Bo	Locus of sema	28	621	76	14,37	1.6	616	70	13,23	1.8	-100	w	1.10	27	0,20710527	73,0616178	0,06843539	0,06644212
Study13	2003	Damian & Bo	Locus of sema	28	657	83	15,69	4.2	641	78	14,74	1.2	0	w	3.05	27	0,50621099	80,5388105	0,19866199	0,19287571
Study13	2003	Damian & Bo	Locus of sema	28	669	90	17,01	5.0	667	85	16,06	3.0	100	w	1.10	27	0,20710527	87,535707	0,02284782	0,02218235
Study13	2003	Damian & Bo	Locus of sema	18	621	65	12,29	2.4	619	66	12,48	1.8	-200	p	1.28	27	0,23918591	65,5019084	0,03053346	0,02907949
Study13	2003	Damian & Bo	Locus of sema	18	603	62	11,72	2.4	607	61	11,53	1.8	-100	p	1.28	27	0,23918591	61,5020325	-0,0650385	-0,06194143
Study13	2003	Damian & Bo	Locus of sema	18	586	79	14,92	2.0	589	74	13,99	1.2	0	p	1.28	27	0,23918591	76,5408388	-0,03919476	-0,03732835
Study13	2003	Damian & Bo	Locus of sema	18	586	72	13,61	3.2	584	72	13,61	3.8	100	p	1.28	27	0,23918591	72	0,02777778	0,02645503
Study14	2018	Gauvin, Jones	No lexical con	20	744	87,65	19,6	9.3	718	78,71	17,6	4.4	0	w	3.22	19	0,59417685	83,3000198	0,31212478	0,2989364
Study15	2014	Damian & Spa	Processing dif	48	711	132	19,05	5.4	673	116	16,74	5.3	0	w	5.34	47	0,61450146	124,257797	0,30581582	0,30080245
Study16	2013	Shao, Meyer	Selective and	88	895	107	11,41	4.3	856	96	10,23	4.0	0	w	7.76	83	0,64843064	101,648906	0,38367358	0,38031784
Study17	2020	Jescheniak, W	Semantic inter	32	911	118,8	21	3.8	852	107,48	19	1.6	0	w	6.26	31	0,74721251	113,281487	0,5208265	0,50769642
Study18	2014	Hutson & Dar	Semantic grad	26	843	130	25,49	2.8	803	101	19,8	2.2	0	w	4.63	25	0,67943729	116,406615	0,34362308	0,33277183
Study18	2014	Hutson & Dar	Semantic grad	64	731	109	13,64	2.4	708	94	11,75	1.5	0	w	2.16	63	0,26258492	101,776716	0,22598489	0,22324013
Study19	2020	Cai, Ouyang,	The effect of t	20	844	67	14,98	1.7	816	55	12,3	1.5	0	w	4.62	18	0,73654708	61,2943717	0,45681193	0,43751001
Study20	2018	Vromans & Jc	The interplay l	37	715	118	19,39	2.8	700	109	17,92	2.8	0	w	3.36	36	0,48860337	113,589172	0,13205484	0,12920474
Study21	1998	Feyereisen, D	Why Do Pictu	24	950	138	28,16	3.1	924	77	15,71	1.7	0	w	3.52	23	0,59169776	111,743009	0,23267675	0,22465341

Legend for the dataset excerpt:

- Orange cells in the “distractor” column indicate word distractors.
- Blue cells in the “distractor” column indicate sound distractors.
- Green cells in the “distractor” column indicate picture distractors.
- Dark grey rows mark separate studies.
- Light grey rows indicate new experiments within the same study.
- White rows show conditions with different SOAs within the same experiment.

9.2 R-Markdown script

The following R-Markdown script documents all processing steps, effect size calculations and meta-analytical procedures conducted in this study.

````
---
title: "metatab04"
author: "Katharina Marsic"
date: "`r Sys.Date()`"
output:
---
```{r setup, include=FALSE}
load("metaanalyse_workspace.RData")
```
#Variablen richtige Eigenschaften zuordnen

```{r}
library(tidyverse)
library(readxl)
library(dplyr)
metatab04 <- metatab04 %>%
  mutate(StudyID = as.factor(StudyID), year = as.numeric(year), author =
as.character(author), title = as.character(title), n = as.numeric(n), mr =
as.numeric(mr), sdr = as.numeric(sdr), semr = as.numeric(semr), fqr = as.numeric(fqr),
mu = as.numeric(mu), sdu = as.numeric(sdu), semu = as.numeric(semu), fqu =
as.numeric(fqu), soa = as.factor(soa), distractor = as.factor(distractor), t =
as.numeric(t), df = as.numeric(df))
str(metatab04)
```

#Berechnen r

```{r}
metatab04$r <- metatab04$t / sqrt(metatab04$t^2 + metatab04$df)
```

# Berechnen gepoolte Standardabweichung, um daraus Cohen’s d oder Hedges’ g zu
berechnen

```{r}
metatab04$sd_pooled <- sqrt((metatab04$sdr^2 + metatab04$sdu^2) / 2)
```

#Berechnen Cohen's d und Hedges'g

```{r}
metatab04$d <- (metatab04$mr - metatab04$mu) / metatab04$sd_pooled
metatab04$g <- metatab04$d * (1 - (3 / (4 * metatab04$n - 9)))
```

#Berechnen Standardfehler für g

```{r}
metatab04$se_g <- sqrt((2 * (1 - metatab04$r)) / metatab04$n + (metatab04$g^2) / (2 *
metatab04$n))
```

#Speichern

```{r}
library(writexl)
write_xlsx(metatab04, path = "meta_datas.xlsx")
```

#Meta-Analyse - Gesamteffektstärke
```{r}
library(dmetar)
library(meta)
m.gen_gesamteffekt <- metagen(
  TE = g,
  seTE = se_g,
  studlab = author,
  data = metatab04,
  sm = "SMD",
````
````

```
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  title = "Gesamteffektstärke")
summary(m.gen_gesamteffekt)
```

```
#Forestplot erstellen

```{r}
meta::forest(m.gen_gesamteffekt,
             sortvar = g,
             prediction = TRUE,
             print.tau2 = FALSE,
             leftlabs = c("author", "g", "se_g"))

```

```{r}
install.packages("tinytex")
tinytex::install_tinytex()
```
```{r}
save(metatab04, file = "metatab04.RData")
```
```{r}
load("metatab04.RData")
library(readxl)
metatab04 <- read_xlsx("meta_datas.xlsx")
```
#Subgruppenanalyse nach Distraktortyp
```{r}
m.gen_distractor <- metagen(
  TE = g,
  seTE = se_g,
  studlab = author,
  data = metatab04,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  subgroup = distractor,
  title = "subgroup_distractor")
summary(m.gen)
```
#Forest_Plot_distractor
```{r}
meta::forest(m.gen_distractor,
             sortvar = g,
             prediction = TRUE,
             print.tau2 = FALSE,
             leftlabs = c("author", "g", "se_g"))
```
#Ablenker Wort
```{r}
m.word <- metagen(
  TE = meta_word$g,
  seTE = meta_word$se_g,
  studlab = meta_word$author,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  title = "w_distractor")
forest(m.word,
       sortvar = meta_word$g,
```
```

````
       prediction = TRUE,
       print.tau2 = FALSE,
       leftlabs = c("author", "g", "se_g"))
pdf("forest_word.pdf", width = 12, height = 16)
forest(m.word,
       sortvar = meta_word$g,
       prediction = TRUE,
       print.tau2 = FALSE,
       leftlabs = c("author", "g", "se_g"))

```
#Ablenker Sound
```{r}
meta_sound <- subset(metatab04, distractor == "s")
m.sound <- metagen(
  TE = meta_sound$g,
  seTE = meta_sound$se_g,
  studlab = meta_sound$author,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  title = "s_distractor")
forest(m.sound,
       sortvar = meta_sound$g,
       prediction = TRUE,
       print.tau2 = FALSE,
       leftlabs = c("author", "g", "se_g"))
```
#Ablenker Picture
```{r}
meta_picture <- subset(metatab04, distractor == "p")
m.picture <- metagen(
  TE = meta_picture$g,
  seTE = meta_picture$se_g,
  studlab = meta_picture$author,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  title = "p_distractor")
forest(m.picture,
       sortvar = meta_picture$g,
       prediction = TRUE,
       print.tau2 = FALSE,
       leftlabs = c("author", "g", "se_g"))

```
#Subgruppenanalyse nach SOA
```{r}
metatab04$soa <- as.factor(metatab04$soa)
m.gen_soa <- metagen(
  TE = g,
  seTE = se_g,
  studlab = author,
  data = metatab04,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  subgroup = soa,
  title = "subgroup_soa")
summary(m.gen_soa)
```
#Forest Plot SOA
```{r}
````

```
meta::forest(m.gen_soa,
             sortvar = g,
             prediction = TRUE,
             print.tau2 = FALSE,
             leftlabs = c("author", "g", "se_g"))
```
#Forest Plot SOA = 0ms
```{r}
meta_soa0 <- subset(metatab04, soa == 0)
m.soa0 <- metagen(
  TE = meta_soa0$g,
  seTE = meta_soa0$se_g,
  studlab = meta_soa0$author,
  sm = "SMD",
  common = FALSE,
  random = TRUE,
  method.tau = "REML",
  method.random.ci = "HK",
  title = "SOA = 0 ms")
forest(m.soa0,
       sortvar = meta_soa0$g,
       prediction = TRUE,
       print.tau2 = FALSE,
       leftlabs = c("author", "g", "se_g"))
```
#Berechne die Fehlerdifferenz
```{r}
metatab04$error_diff <- with(metatab04, ifelse(!is.na(fqr) & !is.na(fqu), fqr - fqu,
NA))
sum(!is.na(metatab04$error_diff))
aggregate(error_diff ~ soa, data = metatab04, mean, na.rm = TRUE)
metatab04$error_mean <- rowMeans(metatab04[, c("fqr", "fqu")], na.rm = TRUE)
aggregate(error_mean ~ soa, data = metatab04, mean, na.rm = TRUE)

```
```{r}
aggregate(error_diff ~ distractor, data = metatab04, mean, na.rm = TRUE)
```
```{r}
aggregate(error_mean ~ distractor, data = metatab04, mean, na.rm = TRUE)
```
#speichern
```{r}
library(writexl)
write_xlsx(metatab04, path = "meta_datas.xlsx")
save.image(file = "metaanalyse_workspace.RData")
```
```
```