UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Università degli Studi di Padova

Dipartimento di Psicologia dello Sviluppo e della Socializzazione

SCUOLA DI DOTTORATO DI RICERCA IN SCIENZE PSICOLOGICHE

INDIRIZZO: SCIENZE COGNITIVE

CICLO XV

Retrospective Prime Reliance: A Flexible Retrospective Mechanism for Semantic Priming in Visual Word Recognition

Direttore della Scuola : Ch.ma Prof.ssa Clara Casco

Coordinatore d'indirizzo : Ch.ma Prof.ssa Francesca Peressotti

Supervisore : Ch.ma Prof.ssa Francesca Peressotti

Dottorando : Michele Scaltritti

INDEX

ABSTRACT

Recent evidences (Balota et al., 2008; Thomas et al., 2012) suggest that the cognitive system can retrospectively (i.e., after target presentation) increase its reliance on prime information when target-word recognition is made more difficult by experimental manipulations such as visual degradation. In fact, response time (RT) distributional analyses have shown that for clearly visible target-words the priming effect has the same size in all the portions of the RT distribution. In contrast, for degraded target-words, priming effects increase across the RT distribution, coherently with the idea of an increased reliance on prime information for degraded targets, which would be particularly beneficial for the most difficult responses (i.e., the slowest ones).

The first study (with English-speaking participants), investigated the idea of retrospective prime reliance in the context of an important empirical conundrum within the word recognition literature, produced by the joint effects of stimulus visual quality (SQ), semantic priming and word frequency. The manipulation of these variables, in fact, has traditionally produced constraining results for models of priming (e.g., McNamara, 2005), as well as for visual word recognition models (e.g., Reynolds & Besner, 2004). In Experiment 1, all the three variables have been manipulated within a single speeded pronunciation task, where words and nonwords were randomly appearing as targets. The results indicated that the joint effect of SQ and word frequency on RTs were dependent upon prime relatedness. More specifically, additive effects of SQ and frequency were observed after related primes, while an overadditive interaction was observed after unrelated primes. Distributional analyses showed that this three-way interaction was mediated by slowest RTs and it was hypothesized that the pattern of effects reflects reliance on prime information. To test this hypothesis, in Experiment 2 related primes were eliminated from the list, to produce a context in which there was no reason to rely on prime information. Interactive effects of SQ and frequency found following unrelated

primes in Experiment 1 reverted, in Experiment 2, to additive effects for the same unrelated prime conditions. Note that, in English, additive effects of SQ and frequency are found in standard speeded pronunciation tasks (i.e., with no primes), provided that words and nonwords are randomly intermixed in the target set (as was the case in Experiment 2).

In a second study, the same experiments as in the first one were tested within a different priming paradigm, namely in zero-lag repetition priming (e.g., Ferguson et al., 2009) and within a different language (Italian). Although distributional analyses provided preliminary evidences that retrospective prime reliance is operative even in this context (Experiment 3), cross-linguistic differences were nonetheless observed. More specifically, in English SQ and frequency produce additive effects in a speeded pronunciation task, provided that nonword targets are intermixed with real words (O'Malley & Besner, 2008) and provided that primes (if present) are all unrelated (Experiment 2). This finding does not seem to be replicated in Italian, where the two variables still produced, in Experiment 4, an overadditive interaction despite the presence of nonwords in the target-set and despite the fact that only unrelated primes were presented (exactly as in Experiment 2). It was hypothesized the discrepancy might stem from the fact that, while in English the system needs to place a functional threshold at an earlier processing level in order to overcome the detrimental effect of visual degradation before lexical representations get activated (thus avoiding lexicalization errors), in a transparent language this might not be the case. It was thus argued that in Italian it is sufficient to increase the reliance on sublexical output, without qualitatively altering the activation-dynamics of the system.

The third study explored the possibility that retrospective prime reliance entails episodic retrieval. In a first experiment, English-speaking participants first performed a lexical decision task where SQ and semantic priming were manipulated. After completing the lexical decision and a brief distracter-task, they also performed a recognition memory task on primes presented during the lexical decision. Results showed a trend towards better recognition of those primes that preceded degraded targets, as opposed to clearly visible ones. The result is coherent with the hypothesis that, for those primes that preceded degraded targets, episodic retrieval takes place even in lexical decision, thereby facilitating the recognition of these items in a subsequent memory task. In a second experiment (Italian participants), the effect of SQ in the memory task was not replicated, probably due to specific features of the materials used in the experiment. On the other hand, a strong lexicality effect was found in the memory performance: primes that preceded real words were recognized much better compared to those that preceded nonwords in the previous experimental phase. These results suggest that the interplay between primes and targets, and the cognitive operations required to process them in lexical decision may reflect into the memory traces left by these stimuli.

In conclusion, retrospective prime reliance proved to be a useful theoretical tool to understand the joint effect of semantic priming, SQ, and frequency, thereby proposing a new perspective on this issue. Moreover, preliminary evidences suggest that a retrospective component might be involved even in a zero-lag repetition priming paradigm and that the mechanism beside retrospective reliance might entail the episodic retrieval of the prime’s representation. Most importantly, the results highlight the flexibility and the sensitivity of the reading system to the context (i.e., experimental task, characteristics of the stimuli).

SOMMARIO

Evidenze recenti (Balota et al., 2008; Thomas et al., 2012) suggeriscono che, qualora il riconoscimento delle parole-target sia reso più difficile da manipolazioni sperimentali quali la degradazione visiva, il sistema cognitivo possa incrementare in modo retrospettivo (i.e., dopo la presentazione della parole target) la misura in cui utilizza le informazioni convogliate dal prime semantico. Infatti, analisi della distribuzione dei tempi di reazione (TR) hanno mostrato che, per parole-target chiaramente visibili, l'effetto di priming semantico ha la stessa dimensione in tutte le porzioni della distribuzione dei TR. Diversamente, per parole-target visivamente degradate, l'effetto di priming semantico aumenta drasticamente nei TR più lenti, in accordo con l'ipotesi che il sistema si affidi in misura maggiore all'informazione convogliata dal prime per i targets visivamente degradati e che ciò sia di particolare beneficio per le risposte più difficili (i.e., le più lente).

Nel primo studio (condotto con partecipanti di madrelingua Inglese), l'idea di un meccanismo retrospettivo e compensativo all'interno dell'effetto di priming semantico è stata indagata nel contesto degli effetti congiunti di qualità visiva (QV) dei target, frequenza di parole e priming semantico. In letteratura, la manipolazione di queste variabili ha prodotto, infatti, risultati molto rilevanti per i modelli di priming (e.g., McNamara, 2005) e per i modelli di riconoscimento visivo di parole singole (e.g., Reynolds & Besner, 2004). Nell'Esperimento 1, tutte e tre le variabili sono state congiuntamente manipolate all'interno di un singolo compito di lettura ad alta voce, in cui parole e non-parole comparivano in alternanza casuale come targets. I risultati hanno mostrato come gli effetti congiunti di QV e frequenza dipendano dalla relazione semantica tra prime e target. In particolare, le due variabili producono effetti additivi nel caso in cui prime e target siano semanticamente relati, mentre producono un'interazione sovradditiva nel caso in cui prime e target non siano relati. Analizzando la distribuzione dei TR, si è costatato che l'interazione a tre vie precedentemente descritta è mediata, principalmente,

dai TR più lenti ed è stato conseguentemente ipotizzato che gli effetti riflettano un incremento retrospettivo della misura in cui il sistema si affida alle informazioni convogliate dal prime. Per testare l'ipotesi, nell'Esperimento 2 i prime semanticamente relati sono stati rimossi, al fine di creare un contesto in cui il sistema non avesse alcuna ragione per affidarsi all'informazione convogliata dal prime. I medesimi stimoli (coppie di prime - target non relati) che nell'Esperimento 1 avevano prodotto un'interazione, hanno prodotto effetti additivi nell'Esperimento 2. Si noti che, in Inglese, si riscontrano effetti additivi di QV e frequenza in compiti di lettura standard (senza primes), nel momento in cui parole e non parole appaiano in alternanza casuale come targets (come avveniva nell'Esperimento 2).

In un secondo studio, i due esperimenti precedentemente descritti sono stati replicati utilizzando un paradigma sperimentale diverso, ovvero quello di priming di ripetizione (e.g., Ferguson et al., 2009), con partecipanti di madrelingua Italiana. Nonostante le analisi della distribuzione suggeriscano la presenza di una componente retrospettiva anche in questo secondo contesto (Esperimento 3), i risultati hanno mostrato anche importanti differenze. In Inglese QV e frequenza producono effetti additivi in compiti di lettura nei casi in cui sia parole che non-parole siano presentate come targets (O'Malley & Besner, 2008) e i primes (se presenti) siano tutti non relati (Esperimento 2). In Italiano le due variabili producono effetti sovradditivi (Esperimento 4) nonostante la contemporanea presenza di parole e non parole e nonostante il fatto che i targets fossero preceduti unicamente da primes non relati (esattamente come nell'Esperimento 2). E' stato ipotizzato che la discrepanza nei risultati sia dovuta alle differenze cross-linguistiche (Inglese vs. Italiano). In Inglese il sistema presenta la necessità di variare la propria architettura funzionale assumendo un funzionamento seriale che confini l'effetto di degradazione visiva negli stadi precoci dell'elaborazione, al fine di evitare che l'attivazione di rappresentazioni lessicali produca errori di lessicalizzazione. In Italiano (un linguaggio trasparente) la situazione potrebbe essere differente. In questo contesto potrebbe essere sufficiente affidarsi in misura maggiore all'output della via sub-lessicale, senza una modificazione qualitativa dell'architettura funzionale.

Nel terzo studio è stata esplorata la possibilità che la componente retrospettiva dell'effetto di priming semantico si basi sul recupero episodico della rappresentazione del prime. Nell'esperimento 5 i partecipanti (di madrelingua Inglese) hanno eseguito, durante la prima fase dell'esperimento, una decisione lessicale in cui sono stati manipolati QV e priming semantico. Al termine della prima fase, dopo un breve compito distrattore, i partecipanti eseguivano una prova di memoria di riconoscimento sui primes precedentemente presentati nel compito di decisione lessicale. I risultati hanno mostrato un trend in direzione di un miglior riconoscimento per quei primes che, nel compito di decisione lessicale, precedevano targets visivamente degradati rispetto a quelli che precedevano targets chiaramente visibili. Il risultato è coerente con l'idea che i prime presentati prima di target visivamente degradati siano soggetti a recupero episodico già nella fase di decisione lessicale e che ciò faciliti la prestazione nel compito di memoria. Nell'esperimento 6, analogo al precedente ma condotto con partecipanti di madrelingua Italiana, il tentativo di replicare l'effetto di QV nel compito di memoria non ha avuto successo, probabilmente a cause delle specifiche caratteristiche degli stimoli selezionati. Tuttavia, è stato rilevato, nel compito di memoria, un forte effetto di lessicalità: i partecipanti riconoscevano meglio quei primes che, in decisione lessicale, avevano preceduto parole reali, rispetto a quelli che avevano preceduto non-parole. Questi risultati suggeriscono che le operazioni cognitive condotte in un compito di decisione lessicale, e in particolare l'interazione tra prime e target, modulino le tracce mnesiche lasciate dagli stimoli stessi.

In conclusione, la componente retrospettiva e compensativa descritta entro il meccanismo di priming semantico ha dimostrato di essere un utile mezzo teorico per comprendere gli effetti congiunti di priming semantico, QV e frequenza, proponendo pertanto una nuova prospettiva con cui investigare il tema. Inoltre, evidenze preliminari suggeriscono che la componente retrospettiva sia operativa anche in un paradigma di priming di ripetizione e che il meccanismo sottostante il processo retrospettivo possa comprendere il recupero episodico della rappresentazione del prime. Infine, i risultati sottolineano la flessibilità e la sensibilità del sistema di lettura al contesto sperimentale (i.e., compito proposto, caratteristiche degli stimoli).

PREFACE

The recognition of a given word (e.g., *DOG*) is facilitated by the presence of another semantically related word, or *prime* (e.g., *cat*), compared to when the prime-target pair shares no relationship (e.g., *bag* - *DOG*). In visual word recognition, the first empirical evidence of this phenomenon (the *semantic priming effect*) has been provided by Meyer and Schvaneveldt (1971). In their seminal experiment, participants were instructed to press a given button if both of the simultaneously presented letter-strings were words or, otherwise, to press another button. Responses were faster and more accurate when two semantically related words were displayed (e.g., *doctor* and *nurse*) compared to when two unrelated words were presented (e.g., *doctor* and *butter*). Such a simple effect has been the focus of many dedicated studies (for reviews, see Neely, 1991; McNamara, 2005) and has inspired research on topics such as the nature of semantic representations (e.g., Balota & Paul, 1996), the distinction between automatic and attentional processes (e.g., Neely, 1977), and computational modeling of memory (Ratcliff & McKoon, 1988) and language (Plaut & Booth, 2000).

The comprehension of meaning is the ultimate goal of reading. However, recognizing a single word presented in isolation is obviously different than reading a book, a paragraph, or even a sentence. In fact, most of the model in the field of visual word recognition assumes (sometimes implicitly) that there is a magic moment in word processing, in which the word is recognized, but the meaning has not yet been accessed (Balota & Yap, 2006). Coherently, some computational models of isolated visual word recognition, like the DRC (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), or the CDP+ (Perry, Ziegler, & Zorzi, 2007), are able to simulate many of the benchmark effects found in skilled readers without having a processing stage dedicated to semantics. Under this broader perspective, semantic priming might open a window on the arguably complex interactions between meaning and lexical access (i.e., the magic moment of word recognition). A semantically related prime, in fact, can be considered as the minimal form of semantic context. Enlightening the mechanisms involved in the semantic priming effect might shed some light on the most basic steps towards word and reading comprehension.

Some specifications are necessary. Semantic priming effects can be produced in quite different paradigms (e.g., Swinney, 1979). However, this work is focused on single visual word recognition, that is, on the cognitive operations and representations that lead to the recognition of words presented visually and in isolation. As such, borrowing the term from Neely (1991), the *single-word semantic paradigm*, and the effects produced within it are the leitmotifs of this thesis. Following Neely's (1991) definition, in this paradigm a trial consists of two events: First, the prime (a single word, or nonword) is presented but no overt response is required. Second, the target (another single word, or nonword) is presented, and a response is required. In most of the cases, the task involved is speeded pronunciation, where participants have to name the target as fast and as accurately as they can, or lexical decision, where participants are asked to decide whether the target is a word or a nonword by pressing the corresponding button on the keyboard or on the response-box (of course, trying to be fast and accurate in their responses). Note that this single-word semantic priming paradigm, although is the most common in the field, represent a slight departure from the original Meyer and Schvaneveldt's (1971) procedure. There, primes and targets were presented simultaneously and the response, although was a single one, required the consideration of both elements. In the single-word semantic priming paradigm, on the other hand, primes and targets are two discrete and sequentially arranged events. Moreover, the prime does not require a response: Usually, the instructions simply ask participants to silently read the primes.

This thesis is divided in three parts. The first one (Chapter I) will briefly review some of the benchmark findings in the semantic priming literature, and will discuss some of the models that have been developed to account for these effects. Also, this part will attempt to raise some questions and issues that will be investigated and discussed in greater detail in the following sections. The second part (Chapter II) will present the retrospective prime reliance account and test it against some new evidences about the influence that semantic primes exert on a well-established and important pattern of effects within the field of visual word recognition, more specifically on the joint effects of word-frequency and stimulus visual quality. The third part (Chapters III and IV) will attempt to further specify the prime reliance account by testing its prediction in a different priming paradigm (i.e., zero-lag repetition priming) and by investigating the possibility that the mechanism beside retrospective prime reliance is episodic retrieval. Finally, some tentative conclusions, along with a discussion of limitations and future directions, will be provided (Chapter V).

CHAPTER I. INTRODUCTION

1.1 Theoretical mechanisms for semantic priming

The fact that a given word is recognized more easily when preceded by another semantically related word, compared to when it is preceded by an unrelated one, does not seem very surprising. However, despite its intuitive simplicity (Neely 1991), semantic priming proved to be quite a complex phenomenon, with several related findings that are difficult to subsume under a single theoretical perspective or model. In his seminal review, Neely (1991) pointed out three different perspectives on the processes and cognitive mechanisms involved in the semantic priming effect, namely automatic spreading-activation, expectancy and post-lexical mechanisms. Given the complex and multi-faceted set of findings, Neely (1991) concluded that the model that can account for most of the results is indeed a convolution of all the three theoretical mechanisms.

In this section, the three mechanisms will be briefly reviewed. Note that the review on empirical findings will be selective (the interested reader may find a more extensive review in Neely, 1991; McNamara, 2005) and will focus on those phenomena that enlighten aspects and concepts that represent the core of the empirical investigations reported in the second and third part of this manuscript. In fact, these theoretical frameworks convey ideas and hypotheses that are still central in the most recent development of the field. During the discussion of each theoretical cognitive mechanism, an attempt will be made to underscore its importance in relation to current theoretical frameworks and hypotheses.

1.1.1 Spreading activation

The mechanism of spreading activation (Collins & Quillian, 1969; Collins & Loftus, 1975; Posner & Snyder, 1975a) is based on the idea that semantically related nodes are connected to each other. When one of them gets activated, activation spreads to other related nodes. In the context of the priming effect, this means that the prime (e.g., *cat*) activates not just its own semantic representation, but, at least in part, even other related ones (e.g., *dog*, *pet*, *mouse*, etc…). Clearly, when the target (e.g., *DOG*) is one of these latter representations, it will benefit from the partial activation that has been produced, via spreading, from the prime. The result, in fact, is that the amount of time needed to recognize (i.e., to fully activate) the target is reduced, thereby producing facilitation. It's important to stress the temporal dynamics that this mechanism implies. In fact, the concept of spreading activation might be regarded as the prototype for all *prospective* accounts of the priming effect. In the vein of recent arguments by Balota, Yap, Cortese and Watson (2008) and Yap, Balota and Tan (2012), the term "prospective" is here intended to designate a mechanism that takes place *before* the target is presented. Coherently, spreading activation is a prospective mechanism since it operates before target presentation: In fact, its effect is to actually *pre-activate* the target, thus allowing a faster recognition. Note that, given these premises, prospective mechanisms for priming and pre-activation go hand in hand. Obviously, target pre-activation can be achieved as well with other mechanisms, such as expectancy (see section 1.1.2). Compared to expectancy, however, spreading activation has been traditionally described as *automatic*. Following Neely (1991), I will consider spreading activation "automatic" as it matches all the criteria proposed by Posner & Snyder (1975b). More specifically, it occurs without intention or awareness, is fast, produces facilitation and no inhibition. It's important to note that spreading activation, articulated within the Interactive Activation (McClelland & Rumelhart, 1981) framework, represents one of the key mechanisms in one of the most popular model of priming, that is, the multi-stage model (Borowsky & Besner, 1993; Stolz & Neely, 1995). Clearly, models of this class are prospective in nature (but see Yap, et al. 2012).

Several findings are consistent with spreading activation. The most appealing is probably that the semantic priming effect seems to occur even when primes are presented under the threshold of conscious awareness (i.e., subliminally). In other words, the semantic priming effect is reliable even when primes are presented very briefly (typically for less than 60 ms.) and then masked, such that participants are unable to verbally report the prime (e.g., Balota, 1983; Marcel, 1983). The claim that semantic priming can occur without awareness of the prime itself has not been unchallenged. In particular, Hollender (1986) identified some methodological flaws, particularly about the assessment of whether stimuli were actually subliminal. Recently, the debate has attracted attention again. Van den Bussche, Van den Noortgate and Reynvoet (2009) conducted a meta-analysis on 46 studies published studies and 8 unpublished ones, involving three different tasks: semantic categorization, lexical decision and speeded pronunciation. The details on the criteria of inclusion and on the results are beyond the scope of this manuscript, but it's important to note that only studies in which the procedure ensures a subliminal presentation were included and that evidences for significant semantic priming effects were found for all three tasks.

Another finding that supports the notion of spreading activation in semantic priming is that, when a short amount of time elapses between prime and target presentation, the magnitude of the priming effect is not affected by the proportion of related trials presented in the experimental list. To understand the relevance of this finding, two further elements need to be considered. First, short stimulus onset asynchrony (SOA; i.e., the amount of time that elapses between prime and target presentation), in the order of 200 ms., are thought to reflect automatic spreading activation processes, while long SOA (800 -1300 ms.) are thought to reflect controlled processing driven by limited-capacity attentional resources (see Neely, 1977). Second, with long SOA, relatedness proportion (i.e., the proportion of trials in which the prime is semantically related to the target) affects the magnitude of the priming effect: larger effects are found when the relatedness proportion increases (Neely, 1991; Stolz & Neely, 1995). The idea here is that the relatedness proportion manipulation operates on expectancy-driven priming mechanisms. More specifically, once a prime is given, the generation of a set of expected targets is a process under participants' strategic control (e.g., Becker, 1980; Becker & Killion, 1977; Neely, 1977; Stanovich & West, 1979). As such, it needs time (i.e., a long SOA) to take place. Moreover, given that in the case of unrelated trials the creation of a set of expected targets produces inhibition (Neely, 1977), in order to optimize performance expectancies are not produced when the proportion of related trials is low: otherwise, the costs will outweigh the benefits. In a complementary way, high relatedness proportion prompts the generation of expectancies about the target, thus increasing the (facilitatory) priming effect. At short SOA, the priming effect is reliable, but insensitive to the relatedness proportion manipulation. Such result suggests that the priming effect detected at short SOA is not under strategic control but occurs automatically, or at least without the need of controlled strategic processes.

The counterpart of this reasoning is that spreading activation by itself cannot account for all the effects detected in the priming paradigm. At least at long SOA, controlled and strategic processes seem to intervene in shaping the semantic priming effect.

1.1.2 Priming mechanism based on expectancy

Semantic priming effect may occur via the generation of a set of possible targets, given the prime. Consequently, recognition of the upcoming target is facilitated when this latter one is indeed part of the set of expected words. This mechanism was originally described as slow acting (i.e., it needs time to develop), dependent on a subject's strategic control, facilitatory for related prime-target pairs but inhibitory for unrelated pairs (Posner &Snyder, 1975a).

Expectancy-based mechanisms of priming have been central in Curtis Becker's (1980) verification model. In this model, a (unprimed) visually presented word is first stored in the sensory memory, and its visual features feed information to stored lexical representations (i.e., to the mental lexicon). Words that are visually similar to the target get activated. This set of words is defined as the sensory-set (Becker, 1980). A frequency-ordered, serial and self-terminating search-process starts to operate on this sensory set, looking for the activated lexical entry with the closest match with the visual input. Such a search-process is basically a verification process, in which words of the sensory set are sampled following a frequency-order and then compared with the representation in the sensory memory, until the matching word is found and the target is recognized.

When a prime is presented before the target, it activates other lexical nodes within the lexicon according to their semantic similarity with the prime. For example, a prime like "*cat*" might activate also "*mouse*", "*dog*", and other semantically related words. These activated words are included into the semantic set (or *expectancy* set). When the target is presented, the sensory set gets activated as described earlier, while words in the semantic set are searched through a verification mechanism similar to the one described for the sensory set: the verification process in the semantic set is serial and self-terminating, but is not frequency-ordered, since it proceeds randomly. The search in the semantic set operates before the one in the sensory set. Actually, the search for the target-word in the sensory set starts only if no match is found in the semantic set. If a match is found in the semantic set, the response is executed without recurring to the search in the sensory set. As such, the semantic priming effect is produced because the search into the sensory set and (at least partially) the generation of this latter one are bypassed when the target word has a match in the semantic set (McNamara, 2005). Note that the verification processes, both in the case of the sensory set and in the case of the semantic set, are carried on against the representation activated in the sensory memory. Moreover, even this model shapes the semantic priming effect as an essentially prospective effect: Processes involved in the effect start before the target is presented.

Among the many intriguing aspects of the model and of Becker's theoretical contribution, given the purposes of the present manuscript, it's worth focusing on a critical pattern of effects that has been investigated in this framework: the overadditive interaction detected on reaction times when stimulus visual quality (SQ) and semantic priming are jointly manipulated (e.g., Balota et al., 2008; Becker, 1979; Becker & Killion, 1977; Borowsky & Besner, 1993; Meyer, Schvaneveldt, & Ruddy, 1975). In other words, semantic priming effects are significantly larger when the target is visually degraded, compared to when is clearly visible. From a complementary point of view, visual degradation affects unrelated trials more than related ones.

In Becker's (1980; see also, Becker, 1979) model, visual degradation has an impact on the time needed to generate the sensory set: when targets are degraded, this operation takes longer. On the other hand, the model assumes that storing the representation of the target in the sensory memory is much less affected by visual degradation. The creation of the semantic set, moreover, is not affected by the visual quality of the target, since it is driven by the prime. In the case in which prime and target are related, the search in the semantic set bypasses the one in the sensory set, thus overcoming the detrimental effect of visual degradation for degraded targets. Clearly, when the prime is unrelated, the search in the semantic set would find no match with the representation stored in sensory memory. As such, a frequency-ordered verification process has to be started on the sensory set. In case of degraded targets, the generation of the sensory set would be considerably slowed down, thus magnifying the priming effect. For clear targets, instead, the second verification process is carried on a sensory set that has not been slowed down by visual degradation and the difference between related and unrelated trials in terms of reaction time is less evident.

Stolz & Neely (1995) tested the idea that expectancy-models can account for the semantic priming by visual degradation overadditive interaction. The starting point of this investigation was the fact that the interaction is present even at a short SOA (i.e., 200 ms. see Besner & Smith, 1992; Borowsky & Besner, 1993). The assumption is that, at short SOA, expectancy is not operative (Neely, 1977, 1991; see also Stanovich & West, 1979; 1983). Evidences supporting this assumption are presented in a seminal study conducted by Neely (1977). Several conditions were elegantly tested in the same experiment, but, for the present point, one is particularly important. Participants were specifically instructed to expect a target of a given semantic category (e.g., part of buildings) after a prime belonging to another specific semantic category (e.g., body parts). As such, a prime-target pair such as "*arm - window*", despite being semantically unrelated, was expected. On the other hand, a pair like "*arm - hand*", despite being semantically related, was unexpected. The critical result is that, at long SOA, a facilitation was produced for expected pairs, while inhibition was found for semantically related pairs (of course, this was true just when participants were instructed to expect targets of a different and specific semantic category, once presented with primes belonging to a certain other semantic category; when expectancy was not manipulated, a standard priming effect was found). At short SOA, the results were in sharp contrast: Facilitation was found for semantically related pairs such as "*arm - hand*" (notwithstanding the fact that participants were instructed to expect building parts as targets when the prime was a body part), and no effect was found for expected pairs such as "arm - window". This result suggests that, at short SOAs, there is not enough time to generate expectancies and to rely on them to give the response. In this context, the fact that the overadditive interaction between SQ and semantic priming is found at short SOA, poses some problems to an expectancy-based account for the interaction itself.

Stolz and Neely (1995) tested the presence of the SQ by priming interaction while orthogonally manipulating SOA (200 vs. 800 ms.), relatedness proportion (50% vs. 25 %) and associative strength between primes and targets (strong vs. weak association). As previously discussed, relatedness proportion's manipulation operates on expectancy: Participants are more likely to generate an expected target when this is helpful on most of the trials (i.e., the relatedness proportion is high). On the other hand, they are not likely to engage this mechanism when few related trials are encountered (i.e., the relatedness proportion is low). Traditionally, this claim has been supported by the fact that the priming effect interacts with relatedness proportion: Larger priming effects are found when the relatedness proportion is high. In the context of Stolz and Neely's (1995) experiment, the manipulation of relatedness proportion is cleverly exploited as a marker of expectancy-based priming effects. Whenever the interaction between semantic priming and relatedness proportion is detected, it can be assumed that expectancy is operative. If the semantic priming by SQ interaction is produced by expectancy, such an overadditive interaction would be found only in conjunction with a semantic priming by relatedness proportion interaction (the marker of expectancy-based priming). To further constraint the interpretation of the results, the authors manipulated associative strength between prime-target pairs. Associative strength values are provided by norms collected by Nelson, McEvoy, and Schreiber (1989; 1998) and consist basically in the proportion of times in which a given word (the target) is produced as a first response when participants are asked to generate an associate of a context word (the prime). Therefore, when a prime-target pair is strongly associated, participants are very likely to produce the target, once the prime is given. The intriguing aspect, exploited by Stolz and Neely (1995) to further test the expectancy-based account, is that strongly associated pairs tend to have fewer alternative associates than weakly associated pairs. In other words, for strongly related pairs, given the context word (e.g., *dog*), most of the time different participants produce the same target (*cat*). In few cases, a different response (e.g., *leash*) is given, i.e. an alternative associate. Clearly, the number of alternative associates generated tends to be smaller for strongly associated pairs compared to weakly associated ones. Under the light of Becker's (1980) theory, for weakly associate pairs the prime would tend to generate larger semantic sets, while smaller semantic sets are produced by primes in strongly associated pairs. Overadditive interaction between SQ and priming is produced by the fact that, for degraded targets, the search in the semantic set bypasses the slow generation of the sensory set. Because strongly associated items generate smaller semantic sets (Becker, 1980), it can be hypothesized that the search in the semantic set would be completed before the sensory set is generated by degraded targets, thus overcoming the effect of visual degradation. On the other hand, because weakly associates generate larger semantic sets, the search in these semantic sets takes longer, and does not produce the same benefit as for strongly related pairs. In conclusion, the verification model predicts a reduction (or an elimination) of the overadditive interaction between SQ and semantic priming when materials are weakly associated.

The results reported by Stolz and Neely (1995) did not match the verification model's predictions. At a short SOA, the priming effect did not interact with relatedness proportion. The priming effect detected for strongly associated pairs with clearly visible targets is the same at low and high relatedness proportion (34 ms and 31 ms respectively), suggesting that, when the SOA is short, expectancy is not operative (note that at a long SOA the priming effect was 45 ms for low relatedness proportion and 88 ms for high relatedness proportion). Despite this, the overadditive interaction between SQ and semantic priming was detected. Moreover, the relatedness proportion manipulation affected the joint effects of SQ and semantic priming. The overadditive interaction was present in the high relatedness proportion condition, but turned to additive effects in the low relatedness proportion condition. These results suggest that, although context-sensitive, the SQ by semantic priming interaction does not seem to be mediated by expectancy-based mechanism of semantic priming (see paragraph 1.2.1, for an explanation of this result in a multi-stage IA framework). Moreover, the authors observed that associative strength modulated the SQ by semantic priming interaction only at short SOA, where the interaction was present just for strongly associated pairs. At long SOA, the interaction was produced both by weakly and strongly associated materials. Thus, strength of association plays a role only at short SOA, where the presence of expectancy-mechanism is not likely. The results are once more in sharp contrast with the predictions of the verification model (for further investigations on the role of association strength as a modulator of the SQ by semantic priming interaction, see Robidoux, Stolz, & Besner, 2010).

Stolz & Neely (1995) interpreted the pattern of results in terms of a multi-stage activation model (see paragraph 1.2.4), consistently with similar proposal made in those years (Besner & Smith, 1992; Borowsky & Besner, 1993). Indeed, the complex pattern of interactions produced when semantic priming is manipulated along with SQ and other variables, is probably the empirical evidence that determined the success of activation models over expectancy-verification ones.

1.1.3 Post-lexical priming mechanism

Post-lexical mechanisms offer quite a different perspective on the semantic priming effect. More precisely, in this framework, the prime does not facilitate, or speeds up, target processing: these sorts of mechanisms, in fact, needs that the target has been already processed (at least partially) to operate.

One of the most influential models that falls in this category, is Ratcliff & McKoon's (1988) compound-cue theory, that capitalizes on the strength of the powerful diffusion-model framework (e.g., Ratcliff, 1978; Ratcliff, Gomez, & McKoon, 2004).

According to the compound-cue theory, prime and target are combined into a compound-cue that is used to respond to lexical decision. More specifically, prime and target's familiarity values are combined, and the single combined familiarity (see Jacoby, 1991) values drives the drift-rate into a random-walk diffusion process. Without entering into the details of the diffusion model framework, the compound cue theory is based on the idea that familiarity is exploited in order to execute a lexical decision (e.g., Balota & Chumbley, 1984). The idea is that words are more familiar than nonwords: When a word is particularly familiar (for example because is used very frequently), a quick "word" response can be made. On the other hand, nonwords are unfamiliar and, consequently, unfamiliar words would need more time to generate a "word" response, given that their unfamiliarity would move the evidence towards the "nonword" response. In a priming paradigm, the compound cue generated by a related prime-target pair assumes higher familiarity value compared to an unrelated prime-target pair, thus explaining the priming effect.

The compound-cue framework nicely accommodates a finding that has been very problematic for other theoretical perspectives: the backward priming effect. Consider a prime-target pair such as "*small-SHRINK*": the prime "*small*" is not associated with "*SHRINK*" (participants are not likely to produce "*SHRINK*" when presented with the context word "*small*"), but the target "*SHRINK*" is associated to "*small*" (participants frequently produce "*small*" when presented with the word "*shrink*"). Thus, backward association designate the fact that the associative relation moves from the target back to the prime, as opposed to forward association, where the relation moves from the prime to the target. Intriguingly, semantic priming effects are found even for prime-target pairs with backward association (e.g., Koriat, 1981; Hutchison, 2002; Thomas, et al. 2012). Clearly this kind of effect is problematic for strictly prospective accounts in which, to re-iterate, the priming effect is produced by the target being pre-activated by a related prime. If there is no associative relation moving from prime to target, how might that happen? A compound-cue made by a related pair of words, on the other hand, will look more familiar notwithstanding the direction of the association between the two elements of the compound.

Another account that relies on post-lexical mechanisms is the retrospective semantic matching process, developed by Neely and Keefe (1989) in the context of a hybrid prospective-retrospective three-process model. Focusing on the retrospective semantic matching, the idea is that, in a lexical decision task, after lexical access has occurred but before the response is actually selected/performed, the system can use information about whether the target is semantically related to the prime to drive a "word" response. In other words, the system capitalizes on a specific feature of the task: Nonwords can never be related with a word prime. Hence, if a semantic match with the prime is retrospectively found, then the target must be a word. From this perspective, the finding that priming effects get larger when the nonword ratio increases (Neely, Keefe, & Ross, 1989), can be easily explained. If we consider both word-targets preceded by unrelated (word) primes and nonword-targets preceded by (unrelated) word-primes, nonword ratio is the proportion of unrelated trials in which the target is a nonword. Clearly, if the nonword ratio is high (i.e., most of unrelated trials have nonwords as target), then a retrospective semantic matching mechanism would be quite efficient: if there is no semantic relationship between prime and target, then the target is likely a nonword. Note that relatedness proportion (the proportion of trials with a semantically related primes out of the total trials in which the target is a word) and nonword ratio can be dissociated, and increases in nonword ration produce an increase in the semantic priming effect (Neely, Keefe, & Ross, 1989; see also Neely, 1991; Neely & Keefe, 1989).

One potential limitation of these classes of post-lexical mechanisms, is that they seem to apply just to lexical decision, and as such they cannot offer a complete account of the semantic priming effect, which reliably occurs in pronunciation tasks as well.

1.1.4 Considerations on the three classes of mechanisms

As seen, none of the mechanisms described above is able, by itself, to offer an account of all the findings in field of the semantic priming. Indeed, Neely and Keefe (1989) proposed a hybrid model that was a clever conjunction of all the three mechanism, in order to offer the most complete account of the different findings in the literature (note that many findings have not been considered in the previous paragraphs. The interested reader may find reviews in Neely, 1991; McNamara, 2005). Moreover, only Becker's (1980) verification model has a broader scope that includes visual-word recognition and semantic priming under the same account. Indeed, all the discussed mechanism, ideally, have to be accommodated within a perspective that includes more general processes of visual word recognition.

Actually, productive efforts have moved towards this direction. For example, multi-stage activation models of semantic priming (e.g., Borowsky & Besner, 1993; Stolz & Neely, 1995; Yap et al., 2012) have been developed within the more general framework of Interactive Activation models (McClelland & Rumelhart, 1981), thus offering a nice link to models of visual-word recognition that relies on the same framework, like the DRC (Coltheart et al., 2001) and, at least in part, the CDP + (Perry et al. 2007). In a different theoretical framework, namely in the field of parallel distributed processing, some works have provided deep insights on how the semantic priming effect might be accommodated within extant models of visual word recognition (e.g., Plaut & Booth, 2000).

Remarkably, the field in which these latter models have developed and have confronted each other is given by a well established pattern of results involving the manipulation of word-frequency, SQ and semantic priming effects. Indeed, this pattern of results had and still has a crucial importance in the literature and has puzzled researches for at least 20 years now. This pattern will be the topic of the next section of this manuscript, where an attempt will be made to clarify its many implications.

1.2 Semantic priming, word frequency, and stimulus quality

The joint manipulation of different variables is a powerful tool to pose constraints on theories and models: While a simple main effect can be accounted for in many different ways, more complex data patterns are sometimes able to falsify some of the various accounts (Besner, O'Malley, & Robidoux, 2010; O'Malley & Besner, 2008). In the previous section, we have seen that, in the field of semantic priming models, helpful insights are given by the joint manipulation of the priming effect along with factors such as SOA, relatedness proportion, associative strength and SQ. Clearly, this approach is functional not only for models of semantic priming, but in general for models of visual word recognition (e.g., Reynolds & Besner, 2004).

When considering both models for semantic priming and models for visual word recognition, the three factors of semantic priming, SQ and word frequency have provided results that can be considered particularly challenging and informative. The manipulation of target SQ if often used with the reasonable assumption that it affects processing since very early stages of word recognition (Balota et al., 2008; Ferguson, Robidoux, & Besner, 2009). Effects of word frequency, on the other hand, are assumed to stem from activation dynamics at the lexical level, at least in models with localized representations for words (e.g., Coltheart et al, 2001; Morton, 1969; Perry et al., 2007). Note that these assumptions importantly define the effects of the two variables in terms of time-course within the chain of processing stages that ultimately lead to word recognition.

The pattern of effects obtained by the manipulation of these variables is as follows:

1) Semantic priming and SQ produce an overadditive interaction: larger priming effects are found for visually degraded targets compared to clearly visible ones (e.g., Balota et al., 2008; Becker & Killion, 1977; Borowsky & Besner, 1993; Meyer, Schvaneveldt, & Ruddy, 1975).

2) Semantic priming and target-word frequency produce an overadditive interaction as well: larger priming effects are found for low frequency words compared to high frequency ones (e.g., Becker, 1979; Borowsky & Besner, 1993; Stone & Van Orden, 1992).

3) Frequency and SQ produce additive effect in lexical decision (e.g., Balota & Abrams, 1995; Borowsky & Besner, 1993; Plourde & Besner, 1997; Stanners, Jastrzembski, & Westbrook, 1975; Yap & Balota, 2007) and in a pronunciation task where words are randomly intermixed with nonwords (O'Malley & Besner, 2008). The two variables yield an overadditive interaction, with larger frequency effect for degraded targets, in a pronunciation task where only words are presented (O'Malley & Besner, 2008; Yap & Balota, 2007).

Before discussing the accounts that have been developed to explain the whole pattern, the following paragraphs will make explicit the issues related with each one of the three results listed above.

1.2.1 The semantic priming by stimulus quality interaction

The relevance of this interaction for models based on expectancy has already been discussed in a previous paragraph (see paragraph 1.1.2). However, this interaction can be accounted for even when considering just a mechanism of spreading activation. Such an account often goes under the name of "horse-race" metaphor (Neely, 1991). As already discussed, a related prime pre-activates target's lexical entry, thus bringing activation closer to the threshold of recognition (i.e., full activation). Assuming that visual degradation slows down the rate of target activation, it would have a stronger impact on targets preceded by unrelated primes: The difference between a slow (the degraded target) and a fast horse (the clear target) will increase as a function of the distance that has to be run. A small distance corresponds to targets preceded by a related prime, since these are closer to full activation, and here the difference between slow and fast items would be smaller. Such a metaphor, however, can be misleading: we might be tempted to predict that any manipulation that increases response latencies will produce larger priming effects. This is not the case. Pexman and Lupker (2010; see also Yap et al., 2012) tested whether the presence of difficult nonwords modulates the priming effect. In a lexical decision task, responses for words get slower when nonwords are very word-like (such as "*flirp*"), compared to when nonwords are not word-like (such as "*skltq*"). The authors found that the priming effect is the same when difficult or easy nonwords are used, despite the fact that this manipulation slowed down responses to word-targets to an extent that is comparable to the manipulation of targets' visual quality. It seems that the time required for target processing by itself is not enough to explain these complex patterns and that it is necessary to consider the levels of processing involved by the experimental manipulations.

The intriguing aspect of this interaction, probably, is that an effect that arguably operates at complex levels of representations (i.e., lexical or lexical-semantic representations) such as semantic priming, interacts with a variable (i.e., SQ) that most likely affects early stages of processing, suggesting that processing is indeed interactive and that the activation-dynamics do not operate in an all-or-none unidirectional fashion. Coherently, within the framework of interactive-activation models, some researches (see paragraph 1.2.4) have assigned a peculiar importance to *feedback* from lexical-semantic level of processing to earlier stages (Borowsky & Besner, 1993; Ferguson et al., 2009; Robidoux et al., 2010; Stolz & Neely, 1995). The idea is that the prime pre-activates target's semantic representation and that this pre-activated representation feeds activation back to earlier levels, such as the orthographic lexicon and the level of letter-processing. As a consequence, when a degraded target is presented, it would benefit from pre-activation since early stages. This feedback pathway from semantics to orthographic lexicon and letter-level processing, moreover, appears to be sensitive to the context and to task-specificities. As already outlined, the SQ by priming interaction is present only when the relatedness proportion is high (Stolz & Neely, 1995, see paragraph 1.1.2): The idea is that the feedback from semantics is instantiated only when it's useful, i.e., when it conveys information that facilitates the task on most of the trials.

If we focus on the time-course outlined by this framework, again we are facing a prospective priming mechanism: the primes pre-activate targets' semantic representations and these latter ones feed activation back to earlier levels. However, a recent proposal suggests that the priming by SQ interaction might be based on different dynamics, namely on retrospective mechanisms.

The proposal was put forward by Balota and colleagues (2008) who grounded their arguments on the analysis of the response times' distribution. It's a well-known fact that reaction times (RTs) are not symmetrically distributed around the mean, but rather the distribution consistently appears to be positively skewed. Therefore, when two conditions are compared in a standard statistical analysis based on the means, a significant difference might hide different distributional profiles. In particular, it might reflect: (a) a shift of the RTs-distribution in one condition (b) a change in the tail of the distribution, but no concomitant shift of the modal part (c) a change both in the modal part and in the tail (Balota et al., 2008). These different possibilities are represented in Figure 1. One way to take these aspects into consideration during data analysis is to fit the RTs to a function that captures all the salient aspects of the empirical distribution. For this purpose, many researches have used the ex-Gaussian function (e.g., Balota & Spieler, 1999; Balota et al., 2008; Ratcliff, 1978; 1979; Yap & Balota, 2007), which conceptualizes the RTs empirical distribution as a convolution of two distributions: a Gaussian and an exponential one. Two of the three parameters of the ex-Gaussian function capture the mean (μ parameter) and standard deviation (σ parameter) of the Gaussian component, while the parameter τ captures both the mean and the standard deviation of the exponential component. Without going into further details, a scenario in which two conditions are different due to the shift of one of them would reflect into changes in the μ parameter, while changes in τ would reflect a difference located just in the slowest tale of the distributions. Clearly, changes both in μ and in τ would reflect both a shift and a difference in the slowest tail. A shortcoming of this kind of analyses is that several observations per experimental cell are needed to obtain stable estimates of the parameters (typically, no less than 40): when several variables are manipulated in the same experiment, this might require a too much large number of trials.

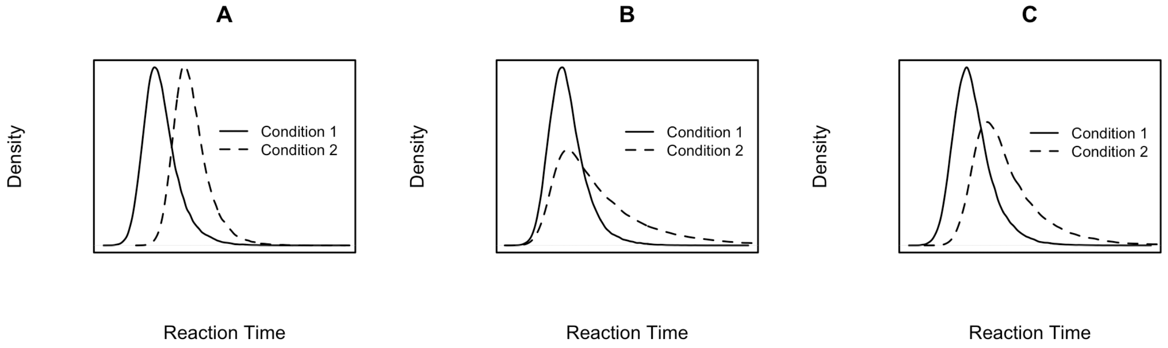

Figure 1. *Hypothetical distributions of RTs for two experimental conditions (solid line = Condition 1; dashed line = Condition 2). Panel A shows a shift of the distribution for RTs in Condition 2. Panel B displays an increase in the tail of the distribution for RTs in Condition 2. Panel C reflects both a shift and an increase in the slowest tail of the distribution for RTs of Condition 2.*

Another way to examine the distribution, at least at a descriptive and non-parametric level, is to perform a Vincentile analysis (Vincent, 1912; Ratcliff, 1979). The procedure consists in dividing the RTs, within each condition and within each participant, into ordered bins. For example, RTs produced by a given participant to a given condition might be divided into 10 bins (10 deciles). The first bin would then contain the fastest 10% of the responses. The next 10% would go into the second bin, and so on, until the tenth bin, in which there will be the slowest 10% of the responses. The mean of the responses within each bin can then be calculated: In this way, each participant will have, for each condition, a mean for each of the 10 bins. The next step would be to average across participants the means within each bin of each condition, and then plot them as a function of bins (represented on the x-axis): this would produce a plot in which is immediately appreciable how RTs in different conditions are changing across the distribution (Figure 2, panel A).

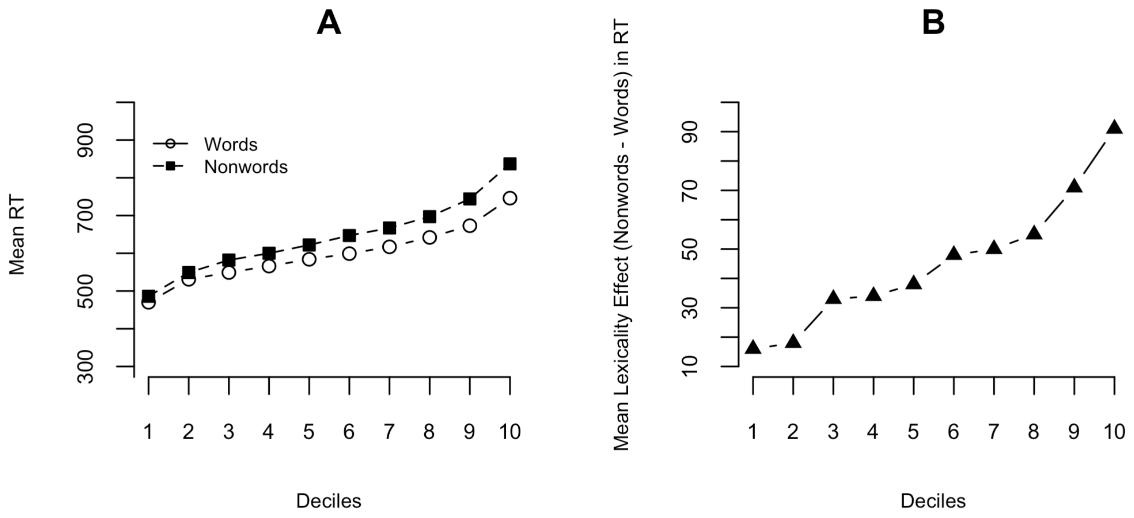

Figure 2. *Plots from a Vincentizing procedure on results from a pilot naming experiment on 24 participants. Panel A represents mean RT for words and nonwords in each one of the different deciles. Panel 2 reports the plot of the net lexicality effect obtained by subtracting the mean RT for words to the mean RT for nonwords in each decile. The lexicality effect appears to grow along the distribution.*

More importantly, one can plot the differences between the means of two conditions across the bins, and obtain a picture of how the effect changes as a function of the location within the distribution (Figure 2, panel B).

How might these kinds of analyses tell us something about the semantic priming by SQ interaction? First it has to be considered that the semantic priming effect detected for clearly visible targets is produced by a shift of the distribution. In other words, the magnitude of the semantic priming effect is constant all across the RTs distribution, with almost equal priming effects for fastest, modal and slowest responses (Balota et al., 2008). This distributional pattern fits nicely with a prospective account of the priming effect, that is, with the idea that semantic primes pre-activates targets' representations, thus facilitating the processing for these latter ones. Indeed, such a headstart mechanism, in which targets preceded by related primes are activated before their actual presentation, is consistent with the observation that, in the related condition, all the distribution on the RTs is shifted towards fastest latencies. Moving to the semantic priming by SQ interaction, Balota and colleagues (2008) pointed out that different accounts for the interaction predict different distributional patterns. If the interaction is mediated by the same prospective mechanism that seems to be operative for clearly visible targets, then one should observe a similar pattern in the degraded condition: One would expect the interaction to be mediated just by a shift in the distribution, with a larger priming effect for degraded targets that is constant all across the distribution (Figure 3, panel A). On the other hand, if we hypothesize that the interaction is produced by an increased reliance on prime information for the most difficult responses, we might expect the interaction to be mediated just by the slowest responses in the degraded condition (Figure 3, panel B). In other words, when presented with degraded targets, participants might increase reliance on prime information in order to resolve such difficult targets, and the amount of such reliance would be proportional to the difficulty of the targets. If this is the case, priming effects would be larger for the slowest degraded responses, i.e., for the most difficult degraded targets. Such a mechanism would not be present when clear targets are presented, since no additional reliance on primes is required for these items that can be processed in a more straightforward manner. Finally, the interaction might be mediated by both kinds of mechanisms, thus producing a shift in the distribution and an increase in skewness (Figure 3, panel C).

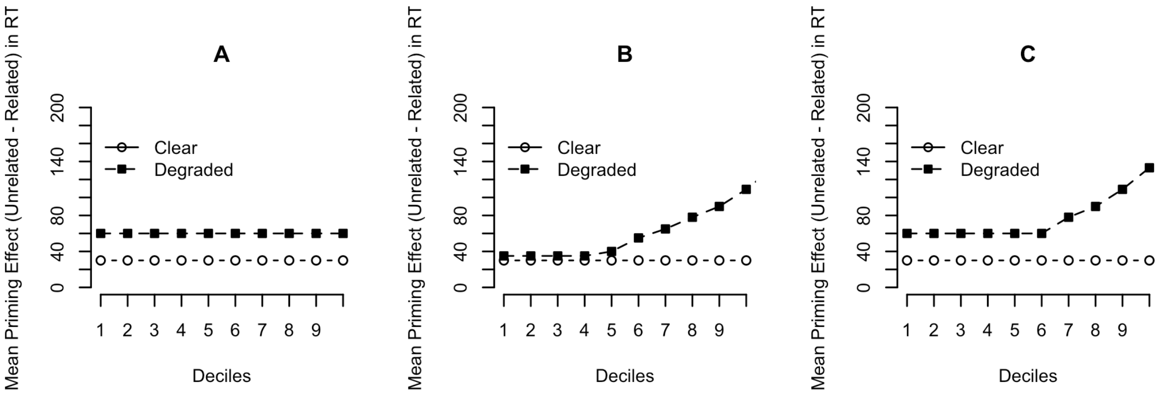

Figure 3. *Hypothetical priming effects as a function of target visual degradation. Panel A represent the case in which the priming by SQ interaction reflects an increase in priming across the whole distribution (shift of the distribution of RTs to related responses in the degraded condition). Panel B represent the case in which the interaction is mediated solely by the fact that priming effects increase dramatically for the slowest RTs to degraded targets. Panel C represents the case in which the interaction is mediated both by a distributional shift and by an increase of the effect in the slowest tail. Adapted from Balota et al., 2008 (Figure 9).*

Note that the prime-reliance mechanism described above strongly differs from pre-activation in terms of temporal dynamics: The increased reliance is invoked *after* the target word is presented, in response to the difficulty of processing a degraded target. For this reason, as suggested by Balota and colleagues (2008; see also Yap et al., 2012), I will consider reliance on prime information as a *retrospective* mechanism, in the sense that it starts after the target is presented, as opposed to prospective mechanisms, that take place before target's presentation.

Balota and colleagues (2008), found that the semantic priming by SQ interaction is produced both by a distributional shift and an increase of the priming effect in the slowest tail for degraded targets, suggesting that the priming effect detected on degraded items is qualitatively different, in terms of distributional features, to the one detected on clearly visible words. More specifically, in addition to prospective processes of pre-activation signaled by the distributional shift, the increased priming effect in the slowest tail suggest the concomitant presence of an increased reliance on prime information for degraded responses. To reiterate, the idea is that, when confronted with a degraded target, the system increases reliance on information conveyed by the prime, and that this increased reliance is particularly strong and beneficial for the most difficult items, i.e., the slowest ones.

This argument has recently received further empirical confirmation and extension. Thomas, Neely, & O' Connor (2012) has shown that retrospective reliance on primes may indeed be a major mechanism underlying the SQ by semantic priming interaction. These authors assessed the presence of this interaction as a function of the direction of the associative link between primes and targets. They compared prime-target pairs with strong backward association and no forward association (e.g., *small* - *SHRINK*), pairs with strong forward association and no backward association (e.g., *keg* - *BEER*) and pairs with a symmetrical association strength (e.g., *east* - *WEST*) in both a pronunciation and a lexical decision task. The results from both tasks indicated that when there is only a forward association between prime and target, no hint of an overadditivity is found. In contrast, when a backward association from the target to the prime is available, a robust overadditive interaction emerged. Moreover, the magnitude of the overadditive interaction produced by symmetrically associated prime–target pairs is comparable to that produced by prime-target pairs with just a backward association. Taken together these findings strongly suggest that the SQ by semantic priming overadditive interaction is mediated by a retrospective mechanism, rather then by pre-activation of the targets' representations by the primes.

1.2.2 *The semantic priming by frequency interaction*

The fact that larger priming effects are found for low frequency words compared to high frequency ones suggests that semantic priming affects lexical stages of processing and thus lexical representations, at least in those models (e.g., Borowsky & Besner, 1993) in which frequency exerts its influence on the rate of activation of lexical nodes (activation is faster for high frequency words) or on the setting of their threshold for recognition (the threshold is placed at a lower level for high frequency words).

Despite the fact that this interaction is regarded as a benchmark finding, its reliability has been recently questioned. In other words, it has been demonstrated that such interaction does not always occur. Yap, Tse, & Balota (2009) examined the joint effects of frequency and semantic priming as a function of vocabulary knowledge (intended as a proxy for lexical proficiency) across different populations (undergraduate students from different Universities). The results showed that the overadditive frequency by semantic priming interaction is statistically significant only for participants that scored relatively low on vocabulary knowledge. For participants who had a high score in vocabulary knowledge, frequency and semantic priming had additive effects. These results suggest that participants differentially rely on contextual information provided by the prime depending on how fluent they are in processing the target. As the SQ by semantic priming interaction, also the frequency by semantic priming interaction seems to be sensitive to contextual factors, namely the fluency of lexical processing. For both empirical results, it seems like the system flexibly considers information extracted by the prime as a function of its utility for target processing.

1.2.3 Additive effects of stimulus quality and frequency

According to Sternberg's (1969) additive factors' logic, two variables that produce interactive effects are affecting at least one common processing stage. On the other hand, two variables that produce additive effects are affecting two different stages of processing (but see McClelland 1979, for different accounts). Within the additive factors perspective, the combined effects of word frequency, SQ, and semantic priming can best be interpreted as suggesting that SQ and word frequency are affecting two separate, discrete and serially organized stages, while semantic context is affecting both of these stages (e.g., Borowsky & Besner, 1993).

The notion of serially organized stages is particularly challenging for the currently most successful models of word-recognition. These models heavily rely on interactive activation mechanisms (McClelland & Rumelhart, 1981). Models such as the DRC (Coltheart et al., 2001) and the CDP + (Perry et al., 2007) implement cascaded activation within an interactive activation framework, and strong additive effects of SQ and word frequency do not easily fall from such a perspective. Indeed, the issue has led to lively debates in the field (e.g., Besner, 2006; Besner & O'Malley, 2008; Reynolds & Besner, 2004; Ziegler, Perry & Zorzi, 2009). More specifically, in these kind of models, as soon as any representation gets activated, activation is immediately forwarded to subsequent stages of processing, which in turn feed activation back to earlier stages. In this scenario, is difficult to interpret, and of course to simulate, additive effects since stages are not working in a serial fashion, but rather activation is flowing in a cascaded and interactive way among them. Notably, Plaut and Booth (2006; see also Plaut & Booth, 2000; Borowsky & Besner, 2006) reported simulations of the full pattern (interactive effects of semantic priming with both SQ and frequency, with concomitant additive effects of SQ and frequency) within a PDP (parallel distributed processing) computational model. Although there were aspects of the data that could be accommodated by the PDP model, there were also some problems (Besner, Wartak, and Robidoux, 2008). For example, whereas humans show the pattern of additive effects of SQ and frequency across a wide variety of stimulus qualities, the model displays either underadditive, additive or overadditive effects of SQ and frequency depending on the size of the SQ effect (but see also Masson & Kliegl, 2012).

Given these premises, it is not surprising that the additive effects of SQ and word frequency traditionally found in lexical decision tasks have been the focus of many investigations. Yap and Balota (2007; see also O'Malley, Reynolds, & Besner, 2007) systematically investigated the joint effects of SQ and word frequency across different experimental tasks and found that the additive pattern holds only for the lexical decision, while interactive effects are found both in pronunciation and semantic categorization. The authors argued that the different pattern found in lexical decision might be related to task-specific operations that engage an early clean-up process that is particularly important for making word/nonword decisions (see also Yap, Balota, Tse & Besner, 2008). This argument is critical because if these additive effects only occur for lexical decisions, then they may not be problematic for recent models of visual word recognition, since task-specific lexical decision operations fall outside their scope.

O'Malley and Besner (2008) hypothesized that the difference across tasks observed by Yap and Balota (2007) might be due to the presence or absence of nonwords. Indeed, they demonstrated that SQ and word frequency also produce additive effects in pronunciation when words and nonwords were randomly intermixed, as in the lexical decision task. O'Malley and Besner argued that when nonwords are present, the activations dynamics within interactive processing stages are changed. More specifically, they claimed that in presence of nonwords the level of letter-processing is thresholded. This means that stimulus information is forwarded to the orthographic lexicon not in a cascaded (and continuous) fashion, but rather only after activation has reached a certain criterion at the letter level. When nonwords are embedded in the list, this should be useful even in speeded pronunciation since, in the case of degraded nonwords, it would prevent the activation of lexical entries that might interfere with the recognition process (possibly producing lexicalization errors).

After having discussed specificities and complexities at the empirical level, is now important to see how theoretical models handle such a rich set of results. Importantly, two models have been proposed to explain the main pattern of results, that is: semantic priming interacts both with SQ and word-frequency while word-frequency and SQ yield additive effects (at least in lexical decision). Some of the further specifications previously addressed (such as the distributional features of the SQ by semantic priming interaction, or the role of nonwords in the target-set) were not explicitly considered when these models have been proposed. Indeed, some of those specific issues have emerged after these models were presented. Nonetheless these models are currently the most promising ones for addressing the complexities of the issue. Moreover, quite recently, researches have tried to improve these models (Yap et al., 2012) or to outline how they are able to handle the results found in most recent investigations (Masson & Kliegl, 2012).

1.2.4 Multi-stage activation model

Multi-stage activation models have developed within the Interactive Activation framework (McClelland & Rumelhart, 1981). Indeed, multi-stage activation models accounting for the complex pattern of SQ, frequency and semantic priming (e.g., Borowsky & Besner, 1993; Stolz & Besner, 1998; Stolz & Neely, 1995) assume, similarly to the original IA model, that word-recognition entails different levels (multi-stage) of representation and processing. Moreover, they assume that connections within each level are inhibitory, while connections between different levels are both excitatory and inhibitory (McNamara, 2005; Stolz & Besner, 1998). Note that, despite these similarities, multi-stage activation models have to make further assumption in order to account for the semantic priming phenomenon. In fact, how might within level inhibition co-exist with within level spreading activation? As previously discussed, a classical way to interpret the semantic priming effect is to argue that a prime activates not just its own semantic representation, but even the ones of the semantic associates. Clearly, such a spreading of activation amongst associates is at odds with the idea of within level inhibition between competing representations. Stolz & Besner (1998) advocated the idea of a between-level spreading of activation. More specifically, when the prime is presented, its lexical activation would not just flow to the corresponding semantic representation, but it would spread to semantic associates as well. Within-level inhibition is still present, but it does not drive the activation of competitors to zero (McNamara, 2005; Stolz & Besner, 1998): The system converges on the target's representation, but it still leaves representations for competitors partially activated. A representation of the model is depicted in Figure 4. When a prime (e.g., *cat*) is presented, corresponding letters are activated at the letter level. Activation then feeds forward to the lexical level, via pathway A, and to the semantic level, via pathway B. As anticipated, activation from the lexical representation of the prime (*cat*) spreads also to its semantic associates (e.g., *dog*) at the semantic level. Critically, the levels are interactive: Activation feeds back from semantics to the lexical-level, via pathway C, and from the lexical-level to letter-level via pathway D. Feedback of activation does not involve just the prime, but its semantic associate as well: the semantic representation of the associate (*dog*) would feed activation back to the lexical- and letter-levels as well. Given these features, the priming effect might arise at all three stages

(McNamara, 2005): When the prime (*cat*) pre-activates the semantic representation of the target (*dog*), this latter representation feeds back activation to the earlier levels, thus diminishing the amount of bottom-up activation needed to activate the target when this is finally presented.

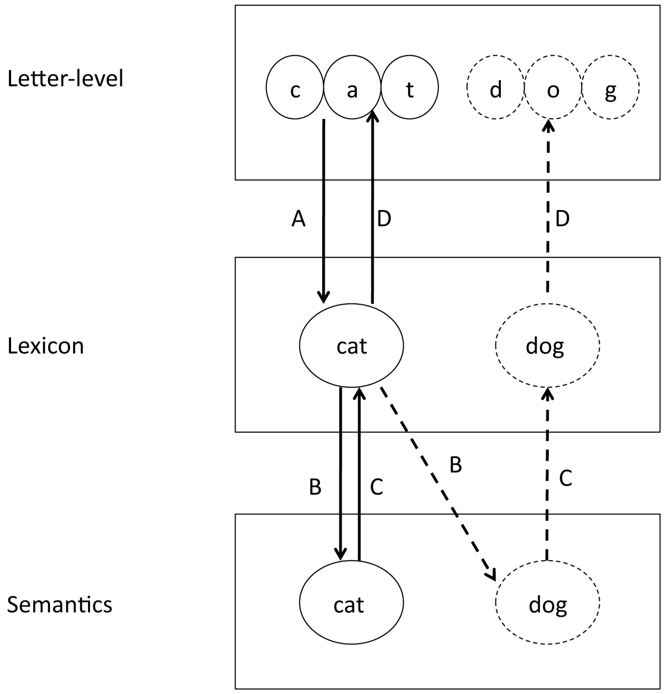

Figure 4. *Representation of the interactive-activation multi-stage model. Presentation of the prime word "cat" activates correspondent letters. Activation then feeds forward to the lexicon, via pathway A, and to semantics, via pathway B. The activation of "cat" in the lexicon spreads also to "dog" in the semantic-level, via pathway B. Activation of "dog" in the semantics feeds back to the lexicon, via pathway C, and then to letter-level, via pathway D. As evident, if the target "DOG" is presented, it would receive support at all the levels of processing, given the pre-activation produced by the prime.*

In the model, SQ affects the rate of activation at the letter level, word-frequency affects mapping from lexical-level to semantics (Borowsky & Besner, 1993; McNamara, 2005), while semantic priming exerts an influence at the semantic stage and, via feedback, at all the other stages (McNamara, 2005). In order to explain the additive effects of word-frequency and SQ, the model has to assume that letter level is thresholded (e.g., O'Malley & Besner, 2008; Reynolds & Besner, 2004): activation has to reach a certain criterion at the letter-level before is forwarded onto lexical representations. In such a scenario, word-frequency and SQ would affect two separate, discrete and serially organized stages, thus producing additive effects. As previously stated, semantic priming affects all three levels. Interactive effects of semantic priming both with SQ and word-frequency, nicely fit with this perspective. The interactions are produced by the fact that semantic priming lowers the threshold (or the amount of activation) needed for recognition. The benefit from a lowered criterion is stronger when the rate of activation is slowed down (as it is for degraded targets) compared to when the rate is faster.

Yap, Balota and Tan (2012) recently proposed an enriched version of the model. A first new aspect consists in the addition of a retrospective mechanism in order to explain the larger priming effect for degraded targets, as suggested by recent evidences (Balota et al., 2008; Thomas et al., 2012). In this new version of the model, the interaction would not be mediated solely by prospective mechanisms, such as pre-activation via feedback, but also by the fact that, for degraded targets, the system retrospectively relies on prime information in order to support target processing. The amount of retrospective reliance and the subsequent influence of the on prime would be proportional to the difficulty of the target: Priming effects are stronger for slower targets in the degraded condition, as suggested by distributional analyses. The second novel feature of the model was introduced by to explain why nonword-type interacts with frequency but yields additive effects with semantic priming (Lupker & Pexman, 2010). In a lexical decision with difficult nonwords (nonwords that are very similar to real words), RTs for words increases, arguably reflecting a more difficult decision. Frequency effects are amplified in this context, whereas priming effects have the same size as the ones detected in a lexical decision task with easier nonwords. Yap and colleagues (2012) attributed these effects to task-specific decisional processes entailed in lexical decision, which would be sensitive to frequency (e.g., Balota & Chumbley, 1984; Yap, Balota, Cortese, & Watson, 2006) and nonword-type (Yap et al., 2006), but not to semantic priming. In this framework, frequency would affect both lexical and post-lexical decisional processes (Balota & Chumbley, 1984), while priming would affect just lexical processes and nonword type would affect just the decisional stage. Hence, frequency would interact both with semantic priming and nonword type, while priming would not interact with nonword type.

1.2.5 Parallel-distributed-processing model

Plaut & Booth (2000) noted that the multistage-model can account for the different patterns of effects resulting from the joint manipulation of semantic priming together with other variables (such as SOA, word-frequency, SQ and others) only at the expense of adding further mechanisms or processing stages. On the other hand, in a parallel-distributed-processing (PDP) network several findings can be accommodated within a single mechanism. The most peculiar feature of PDP models is that they do not implement representations as "localized" in unique nodes, but rather as a pattern of activation involving several densely connected units. Written forms are thus represented by a pattern of activity across orthographic units, while meanings are represented by a pattern across semantic units (Plaut & Booth, 2000). The model is trained to map orthographic forms onto their meanings. Semantic relatedness is produced by the structure of the network itself: Semantically related meanings share more units at the semantic level compared to unrelated meanings. Moreover, the model captures associative relatedness, which is a function of the frequency with which two words have been presented in close sequence (i.e., one after the other) during training. The crucial aspect that makes this model able to simulate the complex pattern of SQ, frequency and semantic priming effects is the fact that a logistic (S-shaped) function maps inputs to activation levels (outputs): within the framework of such nonlinear function, equal differences in input can map onto equal or unequal differences in output, depending on input strength (McNamara, 2005). In other words, the same single mechanism can produce additive or interactive effects, based on the region of the sigmoid function involved in the input-output mapping. Plaut & Booth (2000) developed the model in order to simulate the complex pattern between semantic priming, word-frequency and perceptual/reading ability. However, the same framework can be transposed to explain SQ effects (see McNamara, 2005). On a general level, consider the case of a classic experiment with a 2 X 2 factorial design. Each of the two factors (N and Z) has two levels (n1 and n2, z1 and z2, respectively). When all the combinations of the two factors (n1-z1, n1-z2, n2-z1, n2-z2) fall within the linear region of the function, N and Z would exert additive effects: The same effect of N is detected at both levels of Z. Differently, consider the case in which a level of Z, namely z2a, falls in the upper asymptotic region of the function. There, the effect produced by N would be much smaller than in the linear region, i.e., N and Z produce interactive effects. The two cases are represented in Figure 5.

The model raised a lively debate in the field. Borowsky & Besner (2006) observed that the model cannot simulate experiments in which both additive and interactive effects are produced (e.g., Borowsky & Besner, 1993). In fact, if all the experimental cells of a 2 X 2 factorial design fall into the linear region, additive effects of the factors manipulated should be found, whereas if just one cell falls into the asymptotic region, an interaction should be produced (Besner, et al. 2008).

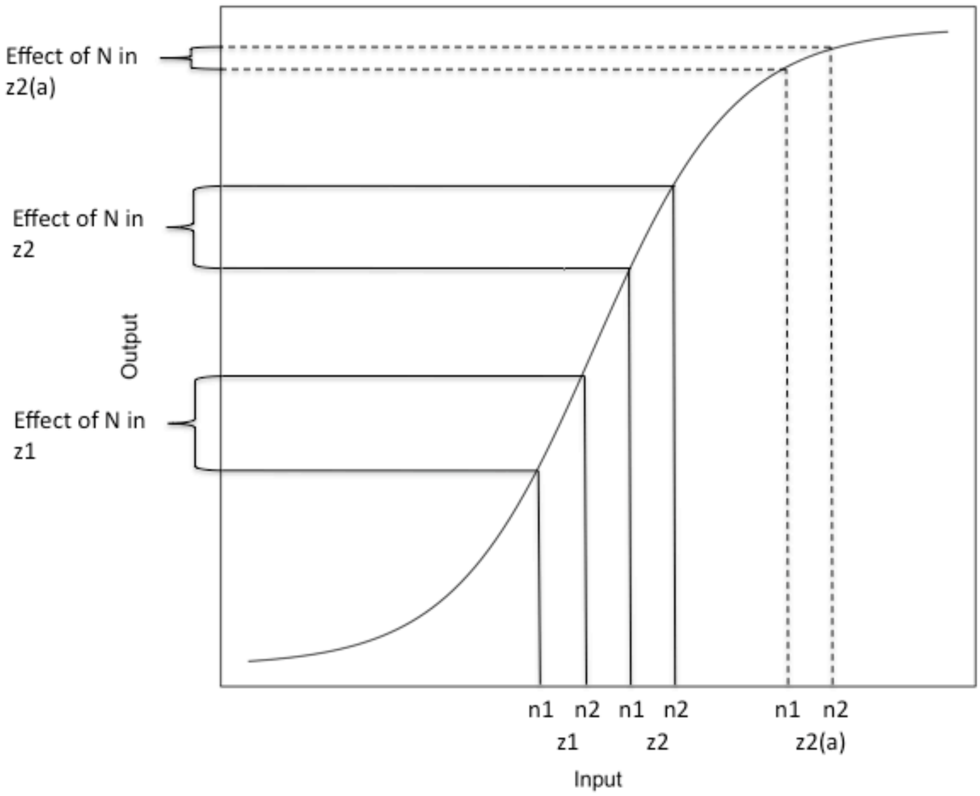

Figure 5. *Representation of the ability of the sigmoid function to produce both interactive and additive effect in a single mechanism. N and Z are two hypothetical experimental factors, each one with two levels (n1 and n2 for N, z1 and z2 or z2(a) for Z). The comparison of z1 and z2 shows how the model produces additive effects, while the comparison of z1 and z2(a) shows how it produces an interaction. Adapted from McNamara (2005, Figure 17.1; see also Plaut & Booth, 2000, Figure 1).*

Plaut & Booth (2006), replied with a single simulation in which both additive and interactive effects of several factors are detected (but see Besner et al., 2008, for concerns about these results). Moreover, Besner and colleagues (2008) found that the model displays underadditive, additive, or overadditive effects of SQ and frequency depending on the size of the SQ effect, whereas humans show an additive pattern across a wide variety of stimulus qualities. More critically, Besner and colleagues (2008) remarked that underadditive effects of frequency and SQ were never observed in human participants.

Recent findings by Masson and Kliegl (2012) seem to contradict this latter claim. These authors explored the joint effects of SQ, frequency and semantic priming as a function of trail history, that is, how the pattern of effects change as a function of the characteristics of the preceding trial (i.e., trial N - 1). Their study offered a rich set of results. For the present purpose, it's important to say that the robust additive pattern of SQ and frequency found in the means-analysis, was hiding two opposite going interactions that became visible only by investigating the pattern as a function of trail history. Specifically, when on trial N-1 a degraded target was presented, frequency and SQ produced an overadditive interaction. When on trial N-1 a clear target was presented, the two factors produced a significant underadditive interaction. These results are critical in two ways: First, they suggest that the additive effects found when considering difference between conditions in terms of overall means, actually hide more complex interactions when trial history is taken into account. Second, they produce evidences for underadditive effects that, although logically possible in the Plaut and Booth (2000) model, were never observed in previous studies.

These observations did not remain unchallenged: Balota, Aschenbrenner, and Yap (in press) recently observed that the underadditive interactions might be a scaling artifact produced by the reciprocal transformation applied on raw RTs (-1/RT). By re-analyzing a series of previously published results these authors consistently showed that the reciprocal transformation, which is quite common in visual word recognition studies that use linear mixed models for statistical analyses (e.g., Andrews & Lo, 2012; Kinoshita, Mozer, & Forster, 2011), selectively reduces the effects at longer latencies (i.e., in the slowest tail of the distribution), producing spurious underadditive patterns.

1.2.6. Considerations on the effects of semantic priming, frequency and stimulus quality in extant models

As seen in previous paragraphs, the effects of semantic priming, word frequency and SQ provide a set of challenging and puzzling results. For now, it seems safe to conclude that none of the models is able to offer an exhaustive account of all the empirical outcomes outlined above (see Masson & Kliegl, 2012, for a similar conclusion). The multi-stage interactive-activation model provides a friendly framework to understand the different set of results, but it does so by increasing the number processing stages and, thus, increasing its structural and functional complexity. Moreover, it's not very clear how a retrospective mechanism could be implemented in such framework. Parallel-distributed-processing models, on the other hand, offer a powerful tool to explain different findings within a single mechanism. However, some critical aspects (Balota, et al., 2012; Besner, et al., 2009; Borowsky & Besner, 2006) are yet to be resolved. Finally, to my knowledge, results from distributional analyses have not been considered in this framework.

To make things even more complicated, the effects previously described cannot be considered complete. In fact, almost all the studies have manipulated just two of the variables within the same experiment, but one might ask what happens when all the three variables are jointly manipulated within the same study. Would the traditional pattern (additive effects of SQ and frequency, paralleled by overadditive interactions of semantic priming with both frequency and SQ) emerge, or some further specificities would become evident? Masson & Kliegl (2012) manipulated all the three variables within the same experiments, but with somewhat different goals: In fact, they implemented all the variables with the specific aim to obtain additive effects, in order to explore them as a function of trial history. For example, weakly associated items and a low relatedness proportion were used, in order to obtain additive effects of SQ and semantic priming (see

Stolz & Neely, 1995), as well as additive effects of semantic priming and word-frequency (see Yap et al., 2009). Therefore, their research is not suited to answer our question.

The only notable exception is the study by Borowsky and Besner (1993), in which semantic priming, SQ and frequency are manipulated within the same lexical decision experiment. Although this study has usually been cited as a confirmation of the traditional set of results, in the next chapter we will see that, when its results are reconsidered, further elements need to be added to the conundrum. This observation was indeed the starting point for the present empirical investigation.

CHAPTER II. STUDY 1: INFLUENCE OF LOCAL AND LIST-WIDE PRIME RELATEDNESS ON THE JOINT EFFECTS OF STIMULUS QUALITY AND WORD FREQUENCY

2.1 Introduction

To reiterate a pattern of effects that has been outlined in detail within the previous chapter, the semantic priming effect produces and overadditive interaction both with SQ and with target's word frequency, while frequency and SQ yield additive effects. Although many studies have manipulated two of the three variables (word frequency, semantic priming, and SQ), to my knowledge, there was only one published study (when this investigation was started) that has jointly manipulated all three variables within the same experiment[1]. Borowsky and Besner (1993, Experiment 3) manipulated SQ (clear vs. degraded), word frequency (measured as a continuous variable) and context (semantically related primes vs. nonword-primes vs. semantically unrelated primes) in lexical decision. Consistently with the literature, within this same study, the authors found additive effects of SQ and word frequency, overadditive effects of SQ and semantic priming, and overadditive effects of word frequency and semantic priming. Borowsky and Besner emphasized the importance of the additive effects of SQ and word frequency on targets preceded by nonword primes and specifically noted that the nonword-prime condition in the experiment was selected "for the purpose of assessing the joint effect of Stimulus Quality and Word Frequency uncontaminated by Context" (Borowsky and Besner. 1993, pg. 826-827).

Borowsky and Besner's (1993) results suggest that when the three targeted variables are jointly manipulated, one obtains the same pattern as when only two variables

---

[1] The Masson and Kliegl's (2012) work, which was not published at the time in which the present study was conducted, was specifically designed in order to obtain additive effects of SQ and semantic priming: as such, is not suited to answer the issues explored here.

are manipulated, further solidifying the empirical conundrum for interactive activation models noted above. However, if one looks more closely at their results, an interesting pattern emerges. Specifically, on related priming trials, frequency and SQ produce clear additive effects, similarly to the nonword prime condition, as noted above. Importantly, however, when targets were primed by unrelated words, SQ and word frequency appear to produce an overadditive interaction, with larger frequency effects for degraded targets. It is not immediately clear how the Borowsky and Besner framework , that is an IA multi-stage model, could account for interactive effects on unrelated trials. Moreover, one might question the emphasis on nonword prime trials producing additive effects of SQ and word frequency, because nonwords may increase the likelihood of dampening input from the lexical system on a trial by trial basis, thereby producing the more additive pattern found in the lexical decision task. Not only: in the context of a semantic priming experiment, for participants is fully predictable that a nonword-prime will not bring any useful information in order to recognize the target.

Because of the potential idiosyncratic nature of the nonword primes, the present study focuses on the joint effects of SQ and word frequency following related or unrelated primes, which in the Borowsky and Besner study produced either additive (following related primes) or overadditive (following unrelated primes) effects. This intriguing pattern may reflect a list-wide reliance on lexical/semantic information, which I will refer to as the *prime reliance account*. Specifically, the presence of related primes and degraded targets may influence how the lexical processing system adaptively adjusts to the demands of the task. This proposal is consistent with a large body of recent literature that investigates the influence of top-down factors, such as task set, task requirements or list composition, in the processing of words from very early stages (e.g., Balota & Yap, 2006; Kiefer & Martens, 2010; Peressotti, Pesciarelli, Mulatti, & Dell’Acqua, 2012).

According to the prime reliance account, because of the difficulty of recognizing degraded targets and the benefit of related primes on half of these degraded trials, participants may increase their reliance on prime information (see Balota et al., 2008, for evidence of such a mechanism). How might an increased reliance on prime information accommodate the Borowsky and Besner's (1993) results of additive effects following related primes and overadditive effects following unrelated primes? First consider targets following related primes. Here, one might expect that the utility of a related prime will be greatest for the most difficult targets, i.e., the low frequency degraded targets. Hence, response latency for these items will produce the greatest facilitation from related primes, thereby decreasing the likelihood of obtaining an overadditive interaction between SQ and word frequency.[2] In contrast, when targets follow unrelated primes, prime information will not be helpful. Consequently, the degraded low frequency words will be most disrupted by failing to access useful information from the prime. This increases the likelihood of obtaining an overadditive interaction between word frequency and SQ.

In light of the prime reliance account of the intriguing Borowsky and Besner's (1993) results, the present study had four goals. First, it further explores the combined effects of the three targeted variables (SQ, word frequency, and semantic priming) within the same experiment. As noted above, the Borowsky and Besner's (1993) study is the only study to jointly manipulate all three variables. Moreover, the interesting additive effects of word frequency and SQ following related primes and the overadditive interactive effects of word frequency and SQ are particularly important to replicate. Second, the present study

---

[2] An examination of the SQ by semantic priming two-way interaction across the reaction time distribution has consistently shown that the disproportionately greater priming effects for degraded targets are found at the slower tail of the reaction times' distribution (Balota et al., 2008; Thomas et al., 2012). This result has been interpreted as evidence of a greater reliance on prime information for the most difficult targets (the ones requiring more processing time) when they are visually degraded. It is worth noting that such a distributional analysis of the semantic priming by SQ interaction can be interpreted as functionally examining the three-way interaction between SQ, semantic priming and frequency, because the fastest RTs in the distribution are likely coming from high frequency words and the slowest, from low frequency words. If that is the case, greater priming effects at the tail of the distributions would imply greater priming effects for low frequency words, i.e.: the hypothesis outlined in the present work.

extends the lexical decision study of Borowsky and Besner to speeded word pronunciation: It is important to demonstrate task independence of the three way interaction obtained by Borowsky and Besner, given some specificities of the lexical decision task (e.g., Balota & Chumbley, 1984; O'Malley & Besner, 2008; Yap & Balota, 2007). Third, the present experiment examines the reaction time distributions to determine if any evidence of the three-way interaction is localized for the most difficult items, i.e., in the slow tail of the reaction times' distributions, as the prime reliance framework predicts. Finally, to further explore the influence of related primes as a list wide effect, a second experiment is reported in which no related primes are included in the experimental list. If the first experiment replicates Borowsky and Besner's overadditive frequency by degradation interaction following unrelated primes, and this interaction is due to the reliance on prime information that is invoked by the presence of related primes in the experimental list, when related primes are removed from the list this interaction should be eliminated for those very same unrelated prime-target pairs.

2.2 Experiment 1

2.2.1 Method

Participants. Thirty-two undergraduate students from Washington University in St. Louis participated in the experiment for course credit. All were native English speakers and reported normal or corrected-to-normal vision.

Design. The experiment was a 2 (related vs. unrelated primes) X 2 (clear vs. degraded targets) X 2 (high vs. low frequency targets) factorial design, with all factors manipulated within participants.

Stimuli. Properties of the items are listed in Table 1. One hundred and sixty prime-target pairs were selected from the Nelson, McEvoy, and Schreiber (1998) norms. Eighty of these pairs included high frequency words as targets while the other 80 included low

Table 1. *Properties of the items used in Experiment 1 and 2*

	LF	HF	t_{greq}	NW	t_{lex}
Primes					
Length	5.34	5.78	- 1.52	5.49	- .32
Freq.	47327	29396	.80	28075	- .83
Log freq.	8.27	8.73	- 1.39	8.52	.07
Orth. N	4.33	3.84	.59	4.17	.15
Phon. N	9.36	7.53	1.13	8.45	.01
Targets					
Length	5.18	4.93	1.03	5.23	1.03
Freq.	4785	80518	- 5.77 *	-	
Log freq.	8.21	10.86	- 20.34 *	-	
Orth. N	4.59	7.13	- 1.03	7.23	3.98 *
Phon. N	10.73	15.73	- .38	-	
Sum Bigram	6737	7227	- .64	13610	10.90 *
Mean Bigram	1518	1714	- 1.60	3182	15.74 *
FAS	.54	.58	- 1.11	-	
BAS	.34	.28	- 1.33	-	

Note. LF = low frequency. HF = high frequency. NW = nonwords. Orth. N = orthographic neighbourhood. Phon. N = phonological neighbourhood. FAS = forward association strength. BAS = backward association strength. Both FAS and BAS are taken from Nelson et al. (1998). All other variables' values have been retrieved from the English Lexicon Project Database (Balota et al., 2007), where frequency values refer to the Hyperspace Analogue to Language (HAL) frequency norms (Lund & Burgess, 1996). t_{freq} = t values generated from an independent samples t-test between items belonging to the LF group versus items belonging to the HF group. t_{lex} = t values generated from an independent samples t-test between items belonging to the nonword group versus items belonging to the word group (collapsed across frequency). t values that correspond to a $p < .05$ are marked (*). Otherwise, the difference was not significant (all ps > .1).

frequency words as targets. Backward and forward association strength were controlled across high and low frequency prime-target pairs, based on the Nelson et al. norms. Frequency values, as well as other variables controlled in the study, were taken from the English Lexicon Project Database (Balota et al., 2007). Onset phoneme, orthographic and phonological neighbourhood density, length, summed and mean bigram frequencies were controlled across high and low frequency targets. Primes for high and low frequency targets were also balanced for frequency, length, orthographic and phonological neighborhood. Unrelated pairs were created by randomly reassigning primes to targets. This re-pairing was done separately for high and low frequency words.

One hundred and sixty pronounceable nonwords were selected from the English Lexicon Projects Database. Words and nonwords did not significantly differ in length. However, following O' Malley and Besner (2008), very word-like nonwords were selected. These nonwords had significantly more orthographic neighbours than words, as well as higher summed and mean bigram frequencies (*p*s < .001). One hundred and sixty words were selected as primes for nonwords and were not different from the primes used for words on frequency, length, orthographic and phonological neighbourhood. Prime relatedness and SQ were counterbalanced across subjects, such that each target appeared equally often in all conditions across participants and no word or nonword was repeated within a participant.

Apparatus and procedure. Participants were tested individually in a dimly lit room, seated at a distance of approximately 50 cm from the computer's monitor. Vocal responses triggered, via an ATR 20 microphone (Audio-Technica), a serial response box (Psychology Software Tools). Data were collected on a Pentium 4 computer using E-Prime 1.1 (Schneider, Eschman, & Zuccolotto, 2001). Participants were asked to silently read the primes and to name the targets aloud as fast and as accurately as possible. A set of 32 practice-trials (16 words and 16 nonwords) preceded the experimental session. For practice word-trials, SQ and prime relatedness (but not word frequency) were manipulated (4 trials per condition). Practice nonword-trials consisted of 8 word-primed clear nonwords, and 8 word-primed degraded nonwords. Primes and targets (words and nonwords) used in the practice session were never presented in the experimental phase. The session lasted about 45 minutes. After every 80 trials, participants were prompted to take a short break. Responses were coded as correct, incorrect or as voice-key errors on-line by the experimenter.

Each trial started with a fixation point (+) presented at the centre of the screen. After 1000 ms, the prime (presented in lowercase) appeared on the screen for 100 ms, followed by a blank screen for the same duration. The target (in uppercase) was then displayed until the voice-key detected a response. If no response was detected, the target disappeared from the screen after 5000 ms. A blank screen was presented for 1800 ms after the response (or after the 5000 ms interval elapsed), producing a clear separation between adjacent trials, which may be necessary for strategic priming effects to occur (Neely, O'Connor & Calabrese, 2010). The letter strings were displayed in 18-point Courier New font on a black background (Red, Green, Blue [RGB] 0, 0, 0). In the bright condition, targets were presented in RGB (65, 65, 65); in the dim condition, they appeared in RGB (5, 5, 5). Primes and the fixation point were always presented in the bright RGB (65, 65, 65).

2.2.2 Results

Response latencies and accuracies were analyzed across both participants and items, thus yielding, respectively, F_1 and F_2 statistics. Context (related vs. unrelated primes), frequency, and SQ were within-subject factors in the analyses across participants. For the item analysis, context and SQ were within-item factors and frequency was a between-item factor.

Trials with incorrect responses (4.10%) or voice-key errors (3.98%) were first removed. The remaining RTs were submitted to a recursive trimming procedure, in which the criterion for outliers' removal was determined by the sample size of each experimental cell (see Van Selst & Jolicœur, 1994). This procedure resulted in the removal of a further 1.68% of the data. In order to minimize the contribution of overall response latency within a participant unduly influencing the results (see Faust, Balota, Spieler, & Ferraro, 1999; Hutchison, Balota, Cortese, & Watson, 2008), the RTs were transformed into within participant z-scores (hereafter referred to as z-RTs) for the ANOVAs.

Response Latencies. Mean response latencies and mean percent errors as a function of condition are displayed in Table 2.

Table 2. *Mean reaction times (RTs) and mean proportion errors (ERR) as a function of context, target frequency and stimulus quality in Experiment 1.*

	Clear			Degraded		
	LF	HF	*FE*	LF	HF	*FE*
RTs						
Unrel	616	607	*12[0,24]*	802	771	*31[18,44]*
Rel	599	584	*15[6,24]*	750	739	*11[-1,23]*
PE	*20[10,30]*	*23[13,33]*		*52[34,70]*	*32[14,50]*	
ERR						
Unrel	.01	.01	*.00[-.01,.01]*	.03	.02	*.01[-.01,.03]*
Rel	.00	.00	*.00[-.01,.01]*	.03	.02	*.01[-.01,.03]*
PE	*.01[.00,.02]*	*.01[.00,.02]*		*.00[-.02,.02]*	*.00[-.02,.02]*	

Note. LF = low frequency; HF = high frequency; FE = frequency effect; PE = priming effect. Unrel. = unrelated. Rel. = Related. 95% confidence intervals for the frequency and priming effects are reported within brackets.

The ANOVA yielded large main effects of SQ (F_1 [1, 31] = 320.91, MSE = .156, p < .001; F_2 [1, 158] = 2499.88, MSE = .05, p < .001), semantic context (F_1 [1, 31] = 66.60, MSE = .036, p < .001; F_2 [1, 158] = 103.20, MSE = .058, p < .001), and word frequency (F_1 [1, 31] = 31.70, MSE = .016, p < .001; F_2 [1, 158] = 11.20, MSE = .12, p < .01). The SQ by context interaction was significant (F_1 [1, 31] = 7.50, MSE = 0.36, p < .05; F_2 [1, 158] = 15.12, MSE = .047, p < .001), but the context by frequency interaction did not reach significance (F_1 [1, 31] = 1.99, MSE = .016, p > .1; F_2 [1, 158] = 1.44, MSE = .058, p > .2). Although this latter result may be surprising, it is fully consistent with previous investigations conducted on the same pool of participants (Yap et al., 2009, see chapter 1, paragraph 1.2.2). Separate analyses revealed that the overadditive interaction between frequency and context was significant for degraded targets (F_1 [1, 31] = 5.06, MSE = .023, p < .05; F_2 [1, 158] = 4.39, MSE = .061, p < .05), but not for the clear targets (Fs < 1). Most important, the three-way interaction among SQ, word frequency, and prime relatedness was significant (F_1 [1, 31] = 4.61, MSE = .02, p < .05; F_2 [1, 158] = 4.26, MSE = .047, p < .05). Planned comparisons indicated that the Frequency by SQ interaction was significant for the unrelated priming condition (F_1 [1, 31] = 5.52, MSE = .022, p < .05; F_2 [1, 158] = 5.57, MSE = .054, p < .05), but not for the related priming condition (Fs < 1).

Accuracy. There were significant main effects of SQ (F_1 [1, 31] = 10.92, MSE = .002, p < .001; F_2 [1, 158] = 28.60, MSE = .002, p < .001) and word frequency in the subjects analysis only (F_1 [1, 31] = 4.22, MSE = .001, p < .05; F_2 [1, 158] = 2.61, MSE = .002, p > .1). None of the remaining effects or interactions was significant.

Distributional analyses. The hypothesis outlined is that the additive and overadditive effects of word frequency and SQ obtained in this experiment are due to the fact that participants are relying relatively more on prime information in order to capitalize on all the sources of information useful to recognize difficult items (i.e. low frequency degraded trials). The reaction time distributions as a function of condition can be used to assess this hypothesis. Specifically, for the degraded targets in the unrelated condition, one would expect a larger frequency effect at the tail of the RT distribution. For clear targets, on the other hand, the presence of an unrelated prime should not be as detrimental, since these targets are processed relatively fluently. Finally, for targets following related primes, there should not be an increase in the frequency effect for the slowest bins in the degraded condition, because the related prime compensates for the increase in target difficulty. Frequency effects as a function of SQ and quintile are plotted in Figure 6.

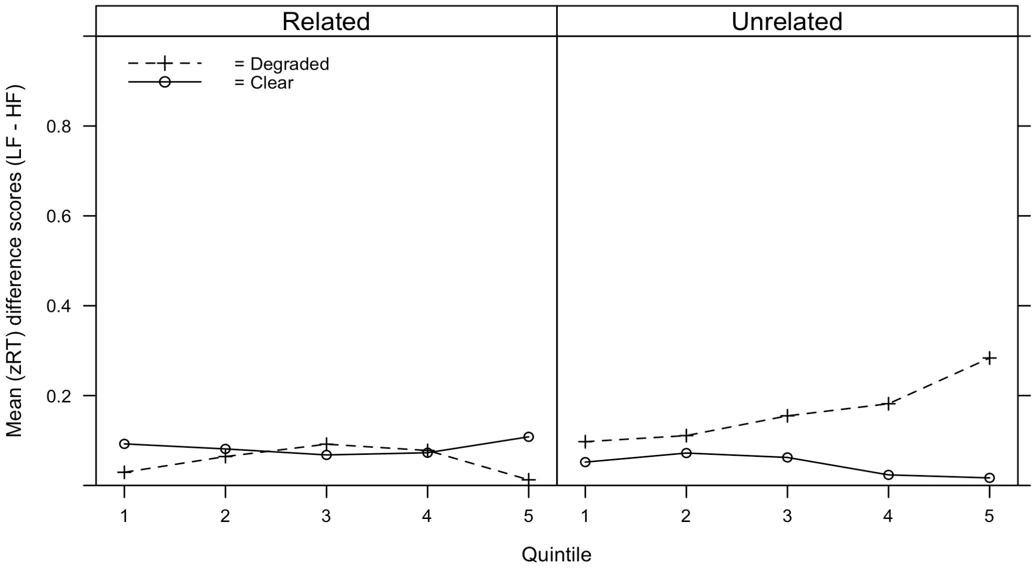

Figure 6. *Experiment 1: Difference in the quintile-means for low frequency versus high frequency words as a function of stimulus quality in words primed by related primes (left-panel) and by unrelated primes (right-panel). HF = high frequency. LF = low frequency.*

As predicted, for targets following related primes (left-panel), frequency exerts a comparable influence on clear and degraded targets, even for the slowest responses. On the other hand, in the unrelated condition (right-panel of the plot), degraded targets show a larger frequency effect at the slowest quintile. To test this directly, data in the slowest quintile were submitted to an ANOVA with prime relatedness, SQ, and word frequency as within-subject factors. The three-way interaction amongst these factors was significant (F

[1, 31] = 6.14, MSE = .085, p < .05). Planned comparison revealed that the SQ by frequency interaction was reliable for unrelated trials (F [1, 31] = 5.73, MSE = .099, p < .05), but not for the related trials (F [1, 31] = 1.19, MSE = .062, p > .2). Note, however, that a hint of stronger frequency effect for degraded targets, in the unrelated conditions, is present from the very first quintiles, suggesting that the interaction is not solely mediated by retrospective reliance.

2.2.3 Discussion

The results from Experiment 1 are clear: There was evidence of a three-way interaction between SQ, prime relatedness, and word frequency. Specifically, there were additive effects of SQ and word frequency following related primes, but clear interactive effects of the same variables following unrelated primes. Hence, the study replicated the intriguing pattern observed by Borowsky and Besner (1993), and extended their lexical decision results to speeded pronunciation, thus showing that this pattern is not task specific. Furthermore, the distributional results indicated that the three way interaction was occurring for the slowest bins, precisely where the prime reliance account predicts. Thus, the present results are consistent with the notion that participants adaptively rely on prime information because (a) some trials involve relatively difficult to identify degraded low frequency targets, and (b) the prime information can be especially helpful on such trials to facilitate processing of these difficult targets. The reliance on prime information produces both additive and interactive effects of word frequency and SQ within the same experiment, depending upon the utility of the prime information.

Experiment 2 was conducted to test directly a specific prediction derived from the prime reliance account. The main assumption of this account is that prime reliance is driven by list composition, i.e. by the presence of useful related prime stimuli that might support the processing of difficult items. If the presence of related primes induced this strategy, the absence of related primes should eliminate it. Therefore, in Experiment 2, we replaced the related primes with unrelated primes such that participants only received unrelated prime-target pairs. Because there will be no utility of prime information when all primes are unrelated, if the prime reliance account is correct, then the overadditive effects of SQ and word frequency following unrelated primes observed in Experiment 1 should turn to additive effects in Experiment 2.

2.3 Experiment 2

2.3.1 Method

Participants. Thirty-two undergraduate students from the Washington University in St. Louis participated for course credit. All were native English-speakers and reported normal or corrected-to-normal vision. None had participated in Experiment 1.

Design. The design was the same as Experiment 1, except that there was no manipulation of prime context. All targets were preceded by unrelated primes.

Stimuli, Apparatus, and Procedure. The stimuli consisted of the same targets (160 words and 160 nonwords) and unrelated primes used in Experiment 1, along with identical apparatus, and procedure.

2.3.2 Results

Errors (3.63%) and voice-key failures (3.38%) were first removed from the analyses. The remaining data were submitted to the same recursive data trimming procedure used for Experiment 1, resulting in the removal of a further 1.8% of the data. Reaction times were again transformed to within participant z-scores for the ANOVAs.

Response Latencies. Mean response latencies and proportion correct as a function of condition are displayed in Table 3. There were main effects of SQ (F_1 [1, 31] = 280.12, MSE = .1, $p < .001$; F_2 [1, 158] = 1912.62, MSE = .036, $p < .001$) and word frequency (F_1

[1, 31] = 19.32, MSE = .013, $p < .001$; F_2 [1, 158] = 6.90, MSE = .09, $p < .05$). Critically, the interaction between the two variables did not approach significance (Fs < 1).

Accuracy. The main effect of SQ was significant (F_1 [1, 31] = 7.85, MSE = .002, $p < .01$; F_2 [1, 158] = 34.11, MSE = .001, $p < .001$). No other effects were significant.

Table 3. *Mean reaction times (RTs) and mean proportion error (ERR) as a function of context, target frequency and stimulus quality in Experiment 2.*

	Clear			Degraded		
	LF	HF	*FE*	LF	HF	*FE*
RTs						
	606	590	*16 [10,22]*	767	756	*11[-1,23]*
ERR						
	.01	.01	*.00 [-.01,.01]*	.03	.02	*.01[-.01,.03]*

Note. LF = low frequency; HF = high frequency; *FE* = frequency effect. The 95% confidence intervals for the frequency effect are reported within brackets.

Distributional analyses. Figure 7 displays the frequency effect for clear and degraded conditions across the quintiles. In contrast to Experiment 1, following the unrelated primes, there was no hint of an interaction between SQ and word frequency for the slowest quintile (F < 1) for the very same unrelated prime-target pairs.

Cross-Experiment Analysis. To further examine the different patterns of results following the same unrelated prime-target pairs in Experiments 1 and 2, we conducted an ANOVA with Experiment, Word Frequency and SQ as factors. As predicted the three way interaction was reliable (F_1 [1, 62] = 4.34, MSE = .018, $p < .05$; F_2 [1, 158] = 6.08, MSE = .035, $p < .05$), strengthening the argument that the presence of related primes within the list in Experiment 1 modulated the presence of overadditive or additive effects of SQ and word frequency.

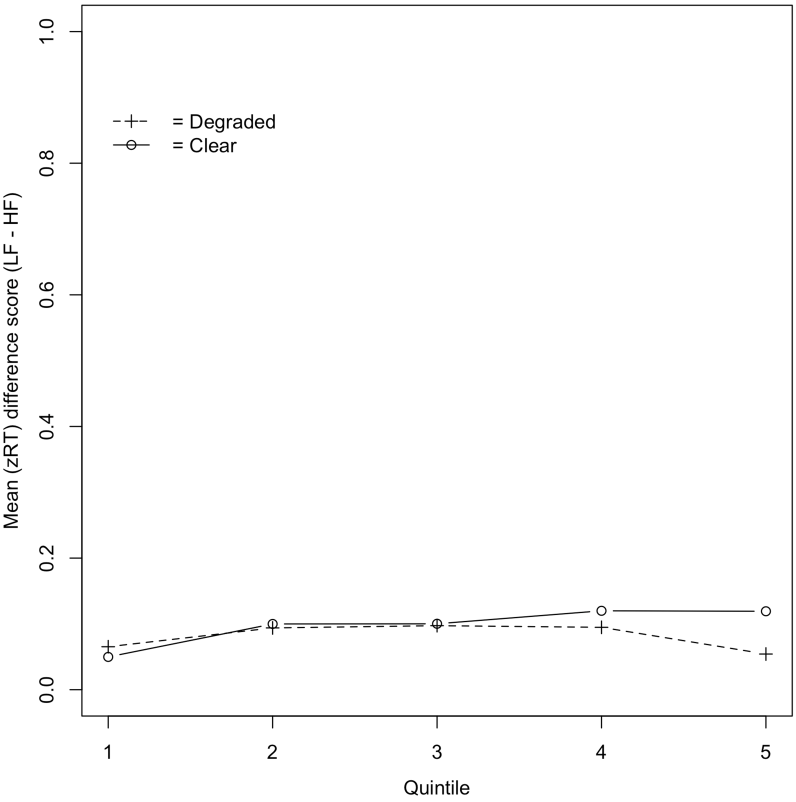

Figure 7. *Experiment 2: Difference in the quintile-means for low frequency versus high frequency targets as a function of stimulus quality. HF = high frequency. LF = low frequency.*

2.4 General discussion

The present study yielded three important patterns of results regarding the theoretically important joint effects of SQ and word frequency. First, both overadditive and additive effects were found in Experiment 1, with additive effects being observed following related primes and overadditive effects following unrelated primes. Second, in contrast to Experiment 1, additive effects of SQ and word frequency were found in Experiment 2 for the same unrelated prime-target pairs when no related prime-target pairs appeared in the stimulus list. Third, the above two observations, were primarily obtained in the slowest quintiles, wherein the most difficult targets were represented.

The present results suggest that participants adaptively rely on prime information when it is useful to identify degraded targets, thereby modulating the presence/absence of the additive effects of SQ and word frequency. First, consider the results from Experiment 1. The proposal is that the degree of influence of related primes is dependent on their utility in identifying the target. This utility is especially great for the most difficult targets, i.e., the low frequency degraded targets. Hence, response latency for the low frequency degraded targets is particularly facilitated, thereby eliminating the overadditive interactive pattern between SQ and word frequency. In contrast, when the prime was not useful (i.e., the prime was unrelated to the target), the processing of difficult items, i.e., the low frequency degraded words, was disrupted by the failure to find a relationship following unrelated primes, thereby contributing to an overadditive interaction. This hypothesis was supported by the distributional features of the frequency effect as a function of SQ. Specifically, the overadditive pattern was particularly evident in the slowest quintiles, i.e. for the slowest targets.

Importantly, the results of Experiment 2 nicely converge on the prime reliance account. Specifically, because related primes were no longer present in Experiment 2, there was no utility of the prime information to facilitate processing of low frequency difficult targets, thereby eliminating prime reliance. Hence, the overadditive effects of frequency and SQ observed in Experiment 1 following unrelated trials reverted to additive effects for the very same prime-target pairs.

Although Borowsky and Besner (1993) did not focus on the interactive effects of word frequency and SQ in the context of unrelated primes, the present results provide a clear replication and extension of the pattern they obtained in lexical decision performance. That is, both overadditive and additive effects can be observed within the same experimental context. Critically, as noted earlier, the additive effects of SQ and word frequency are difficult to accommodate within standard interactive activation accounts of visual word recognition, and the present results pose a particular challenge to such models by showing that the Borowsky and Besner pattern is not task specific.

Recently, Robidoux, Stolz, and Besner (2010) have advanced a proposal that reconciles aspects of Borowsky and Besner's original results (additive effects of SQ and frequency following nonword primes and overadditive effects following unrelated trials) within an interactive activation framework. According to the authors, the pattern is due to the lexicality of the prime acting as a local (i.e., trial-by-trial) control factor on the activation dynamics. More precisely, the system will operate in a serial fashion (by placing a threshold at the letter-level processing stage) when the prime is a nonword, while it operates with cascaded and interactive activation when the prime is a real word. Although this account is consistent with the pattern obtained with nonwords (additive) and unrelated primes (interactive) in the original Borowsky and Besner results, at first glance it cannot accommodate the additive pattern obtained following related primes: Since related primes are "words", interactive effects should have also been found for these items. However, it is important to note that, in the presence of semantically related primes, the feedback from semantics to the orthographic lexicon (see Besner & Smith, 1992; Borowsky & Besner, 1993; Stolz & Neely, 1995) may exert a dampening effect on the SQ by frequency interaction, thus making less clear what pattern one might predict for this condition. For the present experiments, the critical factor appears to have been the list-level presence of related primes. Specifically, the overadditive pattern following unrelated primes only occurred when related trials were also present in the list (Experiment 1) and became additive once related primes were removed from the list (Experiment 2). Thus, in addition to trial-by-trial control parameters, the present results suggest a list-wide control parameter.

It is noteworthy that list-wide variables have previously been shown to play an important role in shaping the joint effects of SQ and semantic priming. For example, Stolz and Neely (1995, see chapter 1, paragraph 1.2.1) found that the overadditive interaction of frequency and semantic priming obtained for lexical decisions occurs only when the relatedness proportion (the proportion of trials in which the prime-target pair is semantically related) is high. When the relatedness proportion is low, additive effects of SQ and priming are found. Clearly, participants are sensitive to list-wide control parameters.

The prime reliance account is also consistent with recent arguments by Bodner and Masson (Bodner & Masson, 1997, 2001, 2003, 2004; Masson & Bodner, 2003). These authors argue that in semantic priming experiments, the prime is encoded as an episodic representation that can be retrieved to facilitate target identification. Critically, such retrieval is a function of prime utility: it will occur only when the payoff is high (e.g., when the relatedness proportion is high). In the present first experiment, the presence of degraded low frequency targets clearly produces difficulty in lexical processing, and so the utility of using the prime would be relatively high. When confronted with degraded stimuli, the system should recruit information from available sources (the primes), provided that these primes have been useful on previous trials, i.e., a list-wide context effect. This would produce the strongest benefit for the most difficult targets following related primes, yielding the additive patterns of word frequency and SQ, and the overadditive effects of word frequency and SQ following unrelated primes. Of course, when the prime stimulus is no longer useful for target recognition, the system reverts back to additive effects of word frequency and SQ, as in Experiment 2.

Interestingly, Thomas et al. (2012) have recently shown that a specific type of prime reliance may indeed be a major mechanism underlying the SQ by semantic priming interaction. To resume their results (see chapter 1, paragraph 1.2.1), the overadditive interaction between SQ and semantic priming was found only when a backward association from the target to the prime was available, thus suggesting that a retrospective mechanism was implied. The prime-target pairs in the present study were not selected to test for the role of backward association strength directly, since prime-target pairs contained both forward and backward association. Nonetheless, in order to explain the pattern obtained, the present study propose a mechanism similar to the one outlined by Thomas and colleagues (see also Balota et al., 2008). That is, target degradation triggers the retrieval of local prime information. The system relies on this information depending upon the difficulty of target processing.

The Thomas et al. study nicely demonstrates a specific prime retrieval mechanism underlying the SQ by priming interaction. However, the present results could also be viewed as consistent with a more general compensatory activation account proposed by Stanovich and West (1983; see also Stanovich, 1980; Stanovich & West, 1979; 1981). According to this perspective, difficulty in lexical processing produced by degrading targets can trigger greater reliance on prime information. Although the general compensatory mechanism was developed primarily in the context of sentence processing, the extension of this general mechanism of increased top down compensation for difficult-to-process targets to single word recognition is clearly within the spirit of the Stanovich and West's account.

Finally, an interesting question arises when one considers the size of the frequency effect across experiments. The current hypothesis is that one finds additive effects of frequency and degradation following related primes in Experiment 1 due to the fact that the presence of related primes engages a top-down influence, which is particularly beneficial for low frequency degraded targets that are related to the prime. If that is the case, one might expect an overall smaller frequency effect in the related conditions of Experiment 1, compared to the unrelated conditions of Experiment 2, with RTs to low frequency degraded targets yielding a relative greater speedup following the related primes in Experiment 1, compared to the unrelated primes of Experiment 2. Although this pattern occurred across the related and unrelated conditions within Experiment 1, it did not occur when comparing the related conditions of Experiment 1 to the unrelated conditions of Experiment 2. So, although it is the case that the unrelated prime condition produces a relative slow-down in the degraded low frequency condition (comparing the unrelated vs. related prime conditions in Experiment 1), it is does not appear that the related condition produces a relative facilitation in the degraded low frequency condition (comparing the related prime conditions of Experiment 1 to the unrelated prime conditions of Experiment 2).

How might one reconcile this pattern? I would argue that the presence of related primes in Experiment 1 and their absence in Experiment 2 produced qualitatively different types of processing. Specifically, as Robidoux et al. (2010) suggested, the conditions of Experiment 1 are more likely to produce cascaded interactive processing, whereas as O'Malley and Besner (2008) have argued the conditions of Experiment 2 are more likely to produce letter-thresholded processing. To further evaluate the hypothesis that related primes produce a larger benefit for the most difficult items, the RTs distributional features were further explored. One would predict that the priming effect would be greater for the most difficult items, i.e., those items at the slowest quintiles. Moreover, this increase across quintiles should be larger for low frequency words than for high frequency words. Figure 8 displays the priming effects for the degraded conditions as a function of word frequency across quintiles. As shown, there is an increasing priming effect across quintiles that is indeed larger for the low frequency words compared to the high frequency words. This is consistent with our suggestion that the related primes are particularly beneficial for the difficult, degraded, low frequency targets, thereby contributing to the additivity following these items. In conclusion, the present results are consistent with the growing evidence that individuals rely more on prime information under conditions in which the target is degraded (see Balota et al., 2008; Thomas et al., 2012). However, the present data do not definitively rule out the possibility that the pattern is produced solely by unrelated primes interfering more with the processing of degraded low frequency targets (rather than by both this mechanism *and* a greater facilitation for low frequency degraded targets by related primes). One potential way to address this issue would be to re-run Experiment 1 adding a baseline condition to separate inhibitory unrelated priming effects from facilitatory related priming effects. Of course, this requires a truly neutral baseline condition to measure facilitation and inhibition, which is extremely difficult if not impossible to do (see Jonides & Mack, 1984, for a discussion of this issue).

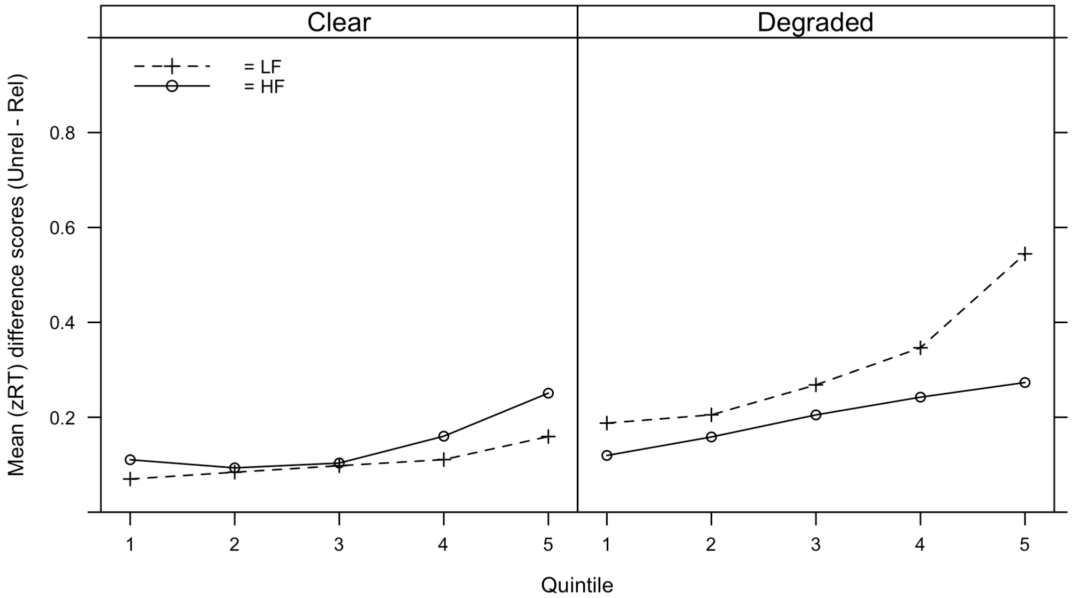

Figure 8. *Experiment 1: Difference in the quintile-means for unrelated versus related trials as a function of frequency in visually clear (left-panel) and degraded (right-panel) target-words. HF = high frequency. LF = low frequency.*

The present results underscore the adaptive flexibility of the lexical processing system to list-level contextual factors by showing that an increased reliance on primes is adopted primarily for difficult stimuli (i.e., degraded, low frequency words), and only in certain conditions (i.e., when some primes in the experimental list are useful). The notion is that the system, while attempting to fulfill the goals of the task, modulates its control parameters to exploit all useful sources of information. Such a modulation could be accomplished via an attentional control system that would bias different modes of processing, according to task-demands (e.g. Balota & Yap, 2006; Pohl, Kiesel, Kunde, 2010; Vachon & Jolicœur, 2011). In this light, it is interesting to note that the stimulus onset asynchrony in the present study was only 200 ms, which has typically been viewed as reflecting more automatic influences of the prime (e.g., Neely, 1977). Apparently, these control parameters can be adjusted even at very short prime-target stimulus onset asynchronies.

The present results add an important finding to a growing literature that suggests the reading system easily adapts to the goals of a task and that this has considerable influence on the theoretically important joint effects of SQ and word frequency. As already outlined, this literature has shown that the joint effects of these variables changes as a function of: (a) experimental task (Yap & Balota, 2007), (b) type of nonwords included in a lexical decision task (Yap et al., 2008), (c) participants' lexical proficiency (Yap et al., 2008) and (d) presence vs. the absence of nonwords in a pronunciation task (O'Malley & Besner, 2008). The present results add (e) the relatedness of the primes within an experiment and the overall list structure to this list.

CHAPTER III. STUDY 2: REPETITION PRIMING AND THE JOINT EFFECTS OF STIMULUS QUALITY AND WORD FREQUENCY

3.1 Introduction

In the previous chapter, the prime reliance account was introduced. According to this framework, when the system faces a degraded target, it retrospectively relies on prime information in order to facilitate target processing. This mechanism is particularly helpful for the most difficult targets, i.e., the slowest ones. Coherently, larger priming effects are found in the slowest tail of the RTs distribution for degraded targets. However, when the prime is not related to the target, retrospective reliance hinders processing of the most difficult targets. These dynamics can explain why frequency and SQ produce additive effects when the target is preceded by a related prime, while they produce an overadditive interaction when the primes are unrelated. More specifically, the reliance on semantically related primes is particularly beneficial for the most difficult degraded words: the low frequency ones. This speeds up recognition of such degraded low frequency words, thus decreasing the frequency effect detected in the degraded condition to the extent that this effect is now comparable to the one detected on clear targets (i.e., SQ and frequency produce additive effects). On the other hand, when the prime is unrelated, the same mechanism hinders recognition of the most difficult targets, namely the low frequency words. As such, low frequency degraded words are slowed down more than other stimuli by the presence of an unrelated prime. This selective slowdown enhances the frequency effect detected in the degraded condition with respect to the clear condition, thus explaining the overadditive interaction between SQ and frequency.

In order to further explore this account, in this second study repetition primes were considered. In this paradigm, a related prime is the same word as the following target (e.g., Scarborough, Cortese, & Scarborough, 1977). More precisely, the following experiments will investigate a peculiar instance of such paradigm, namely zero-lag repetition priming (e.g., Besner, Dennis, & Davelaar, 1985; Humphreys, Besner, & Quinlan, 1988; Ferguson et al., 2009), where the target immediately follows the prime, exactly as in a single word semantic priming paradigm. Intuitively, such a scenario appears to prompt a more prospective mechanism: Primes that are the same word as targets (repeated primes), displayed in close temporal proximity (i.e., 200 ms before the target) to the target and with no intervening items in between, clearly would pre-activate targets' lexical representation (along with its letters and phonology). If that is the case, one would predict a very different pattern of results in this second study, compared to the first one. More specifically, if repetition priming entails a purely prospective mechanism, additive effects would be found both after repeated and unrelated primes. As argued in the previous chapter, the overadditive interaction between SQ and frequency detected in presence of unrelated primes (within a semantic priming paradigm) is produced by the retrospective prime reliance. Coherently, when this mechanism was not instantiated, additive effects of SQ and frequency were found. In summary, in a scenario where only prospective processes mediate priming additive effects are predicted given the absence of the retrospective prime reliance.

Note that repetition priming has been implemented by displaying the same targets two or more times across the experimental session, within each participant, with a different number of intervening items (i.e., different lags) between repetitions. Here, as previously noted, repetition priming will be implemented in the same way as semantic priming has been traditionally implemented, with prime and targets as distinct items, and with the prime immediately preceding the targets in a close temporal proximity. While the distributional features of the former type of repetition priming effect have already been discussed (e.g., Balota & Spieler, 1999), for the latter - to my knowledge- that is not the case. The first step, then, would be to consider how this specific instantiation of repetition priming affects different parts of the RTs distribution, and particularly it will be important to see whether, for degraded targets, the repetition priming effect has a stronger influence in the slowest tail. As discussed in detail, increased priming effect for the slowest RTs have been interpreted as evidence of a retrospective mechanism (Balota et al., 2008; Thomas et al., 2012). Hence, if an increase of the priming effect will be detected at the slowest RTs for degraded targets, one would argue that a retrospective prime reliance is at play. Consequently, interactive effects of SQ and frequency are expected after unrelated primes, given the presence of a list-wide retrospective prime reliance mechanism. More specifically, on unrelated trials this mechanism should manifest itself with an increased frequency effect for degraded targets in the slowest quintiles.

In the first experiment, repetition priming, frequency and SQ were jointly manipulated within the same speeded-pronunciation experiment. The predictions depend on the distributional shape of the repetition priming effect, and particularly on the distributional shape of the SQ by repetition priming interaction. If the interaction is mediated by an increase of the priming effect for the slowest responses of the degraded condition (i.e., if retrospective reliance is at play), interactive effects of targets' frequency and SQ are expected in unrelated trials and the interaction should show a particular contribution of the slower RTs (i.e., the interaction should be larger in the slower tail). On the other hand, if larger priming effects are detected for degraded targets, but this increased effect is constant all across the distribution of RTs (i.e., there is no trace of retrospective reliance), an additive pattern is expected. From a complementary point of view, an interaction between frequency and SQ for targets preceded by an unrelated primes would lead to predict that the priming by SQ interaction is, at least in part, mediated by the slowest RTs. To reiterate, this is so because an increase of the priming effect at the slowest tail of the RTs is considered as a marker for retrospective prime reliance.

3.2 Experiment 3

3.2.1 Method

Participants. Thirty-two undergraduate students from the University of Padova participated to the experiment on the basis of voluntary agreement. All of them were native Italian speaker and reported normal or corrected-to-normal vision.

Design. The experiment constituted a 2 (prime relatedness: repeated vs. unrelated) X 2 (stimulus quality: clear vs. degraded) X 2 (target frequency: high vs. low) factorial design, with all factors manipulated within subjects.

Stimuli. Eighty high frequency words and 80 low frequency words were selected as targets (proprieties of targets and primes are listed in Table 4). High and low frequency target words were matched for onset phoneme, and had comparable neighborhood density and length. For each target, a word with different onset and comparable frequency (low frequency primes for low frequency targets, high frequency primes for high frequency targets) was selected to be used as unrelated prime. Primes and target did not differ on frequency, orthographic neighborhood or length. One hundred and sixty pronounceable nonwords were created by changing a letter from words not used as targets. Words and nonwords were matched on initial phoneme, and had comparable neighborhood density and length (ts < 1). Eighty words (40 high frequency and 40 low frequency) were selected to be used as primes for nonword-targets. These primes did not differ from the primes used for word-targets in term of frequency, orthographic neighborhood or length (all ts < 1). For the other 80 nonword targets, the unrelated primes consisted of the unrelated-primes selected for word targets that were not used in that given list (because the correspondent targets are presented with a related prime), according to list rotation. Prime relatedness and SQ, in fact, were counterbalanced across subjects, such that each target appeared equally often in all conditions across participants and no word or nonword was repeated within a participant. Further 16 words (half presented in the clear condition, half in the degraded one) were selected as practice trials. Half of the words in each SQ-condition were presented with a repeated prime (i.e., the same word), the other half were presented with an unrelated prime. Sixteen nonwords (8 clear, 8 degraded) were created specifically for the practice session and all of them were presented primed by an unrelated word. Neither the words selected as target nor the ones selected as primes for the practice-session appeared in the experimental session.

Table 4. *Proprieties of the items used in Experiment 1.*

	LF	HF	t_{freq}	NW	t_{lex}
Primes					
Length	5.73	5.75	-.13	5.66	.45
Freq.	2.33	280.28	-16.05*	141.3	.00
Orth. N	4.66	4.99	-.55	4.68	.30
Targets					
Length	5.75	5.83	-.42	5.64	.38
Freq.	2.21	279.78	-15.68*	-	-
Orth. N	4.44	4.53	-.15	4.68	-.05

Note. LF = low frequency. HF = high frequency. NW = nonwords. Freq. = frequency. Orth. N = orthographic neighborhood density. Frequency values were retrieved from the Colfis database (Laudanna et al., 1995) and then transformed into number of occurrences on 1 million. t_{freq} = t values generated from an independent samples t-test between items belonging to the LF group versus items belonging to the HF group. t_{lex} = t values generated from an independent samples t-test between items belonging to the word group (collapsed across frequency) versus items belonging to the nonword group. t values that correspond to a $p < .05$ are marked (*). Otherwise, the difference was not significant.

Apparatus and Procedure. Participants were tested individually in a dimly lit room, seated at a distance of approximately 50 cm. from a FLATRON F700B monitor. Vocal responses triggered, via an ATR 20 microphone (Audio-Technica), a serial response box (Psychology Software Tools). The experimental procedure and data collection were controlled by a Pentium 4 computer running E-Prime 1.1 (Schneider et al., 2001). Participants were briefly introduced to the experiment and instructed on how to respond using the microphone. They were asked to mentally read the words appearing in lowercase (i.e., the primes) and to read aloud the subsequent letter-string appearing in uppercase (i.e., the targets) as fast and as accurately as possible. Afterwards, the instruction were visually displayed, followed by a practice session consisting of 32 trials. Once the practice session was finished, instruction were synthetically re-presented and participants had the opportunity to ask about eventual doubts or difficulties. The experimental session started as participants pressed the spacebar and lasted about 45 min (320 trials). Every 80 trials, participants were prompted to take short self-terminated breaks. Responses were coded as correct, incorrect or as voice key errors by the experimenter.

Each trial started with a fixation point (+) presented at the center of the screen. After 1000 ms, the prime (written in lowercase) appeared on the screen for 100 ms., followed by a blank screen of the same duration. The target (in uppercase) was then displayed until response. If no response was detected, the target disappeared from the screen after 5000 ms. A blank screen was presented for 1800 ms. after the response (or after the time for the target has elapsed), separating a trial from the following one and allowing the experimenter to code the response. The letter string were displayed in 18-point Courier New font on a black background (Red, Green, Blue [R,G,B] 0, 0, 0). In the bright condition targets were presented in RGB (65, 65, 65,), while in the dim condition they appeared in RGB (5, 5, 5,). Primes and fixation point were always presented in RGB (65, 65, 65,).

3.2.2 Results

Response times and accuracies were analyzed both by participants and items, thus yielding, respectively, to F_1 and F_2 statistics. Prime relatedness (repeated vs. unrelated), frequency (high vs. low), and SQ (clear vs. degraded) were within-subject factors in the analyses across participants. For the item analysis, prime relatedness and SQ were within-item factors and frequency was a between-item factor.

For analyses of RTs, trials with incorrect responses (5.18%) or voice-key errors (2.69%) were removed. The remaining data were submitted to a recursive trimming procedure (Van Selst & Jolicœur, 1994) that resulted in the removal of a further 1.79% of the data. Response times were then transformed into within participants z-scores (z-RTs). Mean RTs and proportions of errors as a function of conditions are listed in Table 5, along with frequency and priming effects.

Response latencies. The main effect of SQ was significant (F_1 [1, 31] = 466.19, MSE = .116, $p < .001$; F_2 [1, 158] = 2,126.43, MSE = .063, $p < .001$), as well as the ones of prime relatedness (F_1 [1, 31] = 303.81, MSE = .045, $p < .001$; F_2 [1, 158] = 517.32, MSE = .066, $p < .001$) and frequency (F_1 [1, 31] = 42.77, MSE = .033, $p < .001$; F_2 [1, 158] = 20.05, MSE = .172, $p < .001$). The SQ by prime relatedness interaction was significant (F_1 [1, 31] =80.8, MSE = .03, $p < .001$; F_2 [1, 158] = 129.98, MSE = .047, $p < .001$), with stronger priming effect for the degraded condition. The SQ by frequency interaction appeared to be significant (F_1 [1, 31] = 10.25, MSE = .023, $p < .01$; F_2 [1, 158] = 7.5, MSE = .063, $p < .01$), with larger frequency effect for degraded targets. Finally, the prime relatedness by frequency interaction was significant as well (F_1 [1, 31] = 7.42, MSE = .023, $p < .05$; F_2 [1, 158] = 5.48, MSE = .066, $p < .05$): priming effects were larger for low frequency words. The three-way interaction did not reach significance in the analysis by subject (F_1 [2, 31] = 2.06, MSE = .039, $p > .1$), and approached significance in the analyses by items (F_2 [1, 158] = 3.52, MSE = .047, $p = .06$). Despite this fact, given the theoretical importance and the a priori nature of the comparison, we separately analyzed the SQ by frequency interaction in targets preceded by a repeated prime versus targets preceded by an unrelated prime. The interaction, in fact, was not significant for targets preceded by a related prime (Fs < 1), while it reached significance for targets preceded by unrelated primes (F1 [1, 31] = 8.13, MSE = .037, p < .01; F_2 [1, 158] = 9.15, MSE = .065, p < .01).

Table 5. *Mean reaction times (RTs) and mean proportion errors (ERR) as a function of prime relatedness, target frequency and stimulus quality in Experiment 3.*

		Clear			Degraded	
	LF	HF	*FE*	LF	HF	*FE*
RTs						
Unrel	605	588	*17[6, 28]*	826	770	*56[32, 80]*
Rep	560	546	*14[2, 26]*	695	672	*23[9, 37]*
PE	*45[34, 56]*	*42[31, 53]*		*131[108,154]*	*98[79,117]*	
ERR						
Unrel	.02	.01	*.01[.00,.01]*	.06	.03	*.03[.00,.06]*
Rep	.00	.00	*.00*	.01	.02	*-.01[-02,.00]*
PE	*.02[.01,.03]*	*.01[.00,.01]*		*.05[.03,.07]*	*.01[.00,.02]*	

Note. LF = low frequency; HF = high frequency; FE = frequency effect; PE = priming effect. Unrel = unrelated. Rel = related. The 95% confidence intervals for the frequency and priming effects are reported within brackets.

Accuracy. Analyses on word-targets revealed a significant effect of SQ (F_1 [1, 31] = 32.058, MSE = .001, p < .01; F_2 [1, 158] = 29.407, MSE = .003, p < .001): more errors were made when words are presented in the degraded condition. The effects of priming resulted significant (F_1 [1, 31] = 31.640, MSE = .001, $p < .01$; F_2 [1, 158] = 28.841, MSE = .003, $p < .001$) with more errors occurring on unrelated-primed targets. The effect of frequency appears to be significant (F_1 [1, 31] = 5.249, MSE = .001, $p < .05$; F_2 [1, 158] = 4.266, MSE = .003, $p < .05$). The interaction between SQ and prime relatedness reached significance (F_1 [1, 31] = 8.822, MSE = .001, $p < .01$; F_2 [1, 158] = 7.444, MSE = .002, $p <.01$): priming effect are stronger on degraded targets' accuracies. The interaction between frequency and SQ did not reach significance (Fs < 1), while the interaction between frequency and prime relatedness was significant (F_1 [1, 31] = 9.769, MSE = .001, $p < .01$; F_2 [1, 158] = 6.635, MSE = .003, $p < .05$). The three-way interaction between SQ, prime relatedness and frequency did not reach significance in the analyses across subjects (F_1 [1, 31] = 2.786, MSE = .001, $p > .1$) while it approached significance in analyses across items (F_2 [1, 158] = 3.099, MSE = .002, $p = .080$).

Distributional analyses. Given the interaction between SQ and frequency detected for unrelated trials, the prime reliance account predicts (a) that the SQ by priming interaction is mediated, at least in part, by the slowest RTs and (b) that the frequency effect for degraded unrelated words grows along the distribution to a larger extent compared to clear unrelated words.

The repetition priming effect as a function of quintile for clear (left-panel) and degraded (right-panel) targets is plotted in Figure 9. While for clear targets the repetition priming effect is overall constant across the RTs distribution, for both high and low frequency degraded items, it appears to dramatically increase in the slowest quintiles. This is the pattern observed for semantic priming in Experiment 1.

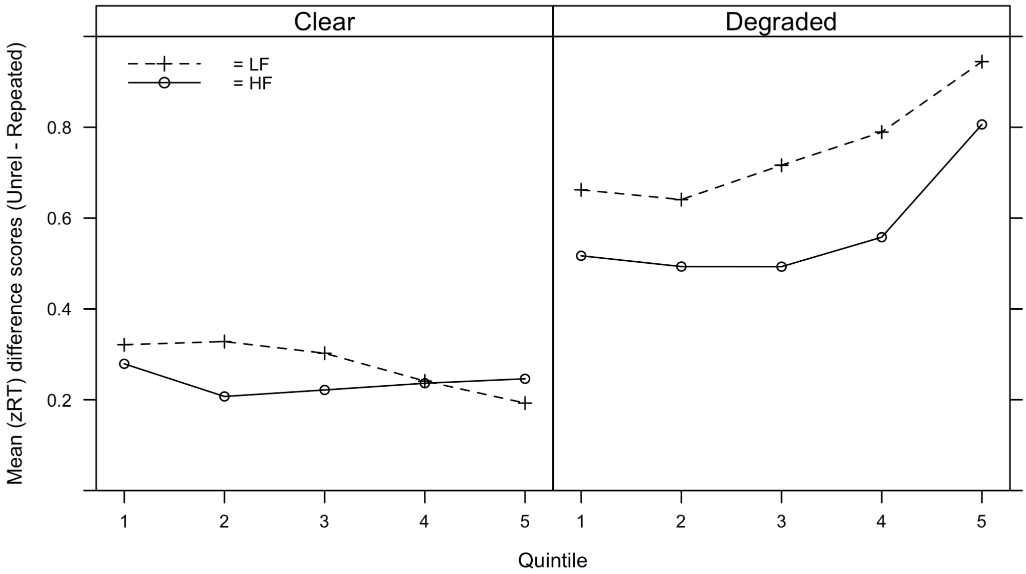

Figure 9. *Experiment 3: Difference in the quintile-means for unrelated versus related trials as a function of frequency in visually clear (left-panel) and degraded targets (right-panel). HF = high frequency. LF = low frequency.*

Turning to the frequency effect (Figure 10), for targets preceded by a related prime (left-panel), the frequency effect is quite the same across quintiles, even though a slight increase seems to take place from the third quintile onwards. For targets preceded by unrelated words (right-panel), we observed the predicted pattern: the frequency effect is "flat" across quintiles for clear targets. In contrast, it becomes larger at slowest quintiles for degraded targets. Note however, that the three-way interaction between SQ, frequency and Quintile tested on unrelated trials does not even approach significance (F < 1). As such, even though visual inspection of the distributional features of the frequency effect for clear vs. degraded unrelated trials (Fig. 10, right-panel) suggests that the two are different, caution is warranted in drawing strong conclusions. Moreover, the presence of the SQ by frequency interaction from the very first quintile suggests that the interaction is not solely mediated by retrospective prime reliance, but might just be emphasized by this latter mechanism. Actually, in the previous study a hint of a SQ by frequency interaction was detected in faster quintiles as well (see Figure 6), but it appears much more consistent here.

.

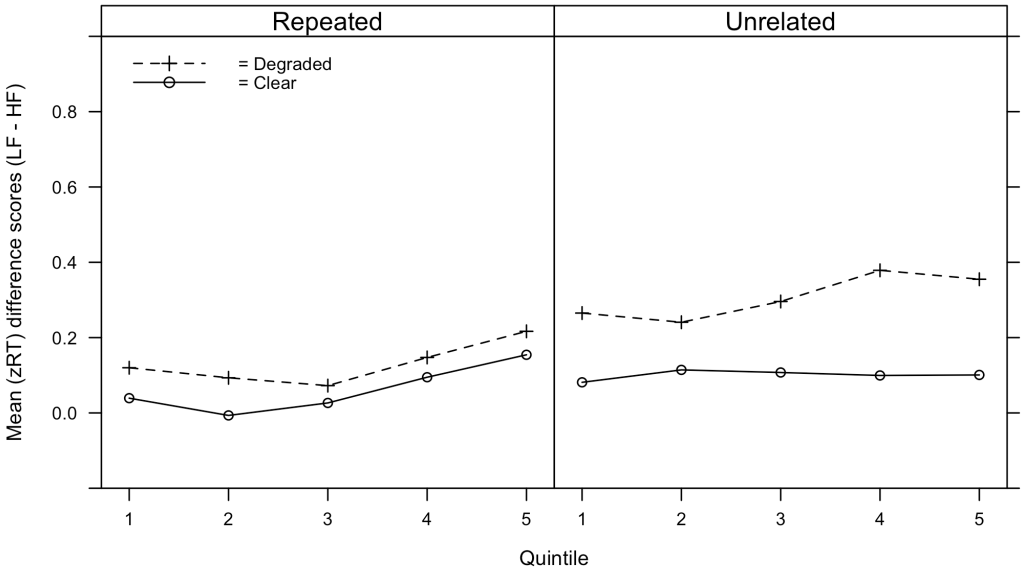

Figure 10. *Experiment 3: Difference in the quintile-means for low frequency versus high frequency words as a function of stimulus quality in words primed by repeated primes (left-panel) and by unrelated primes (right-panel). HF = high frequency. LF = low frequency.*

3.2.3 Discussion

Overall, Experiment 3 provides a picture that is quite consistent with the prime reliance account. A SQ by frequency interaction is detected on targets preceded by unrelated primes and the frequency effect for degraded targets seems to get larger across the distribution, while for clear targets it appear to be constant across different quintiles (Figure 9, right-panel). Moreover, the repetition priming effect for degraded targets, appears to be particularly strong at the slowest RTs, suggesting that the effect is not purely prospective, but entails retrospective reliance (Balota et al., 2008). Before coming to strong conclusions, however, it’s worth exploring what might happen when no repeated primes are presented or, in other words, what shape will the joint effects of SQ and frequency assume when targets are preceded exclusively by unrelated primes. One would expect these effects to be additive, just like O'Malley & Besner (2008) has shown is the case for pronunciation task when nonwords and words are randomly intermixed in the target set (see also Experiment 2). However, given the different language (i.e., Italian) used in the present study compared to the original study, and given the presence of a SQ by frequency interaction even in the faster quintiles of responses to unrelated trials (where retrospective prime reliance might not be operative), it's worth trying to replicate the finding.

3.3 Experiment 4

3.3.1 Method

Participants. Thirty-two undergraduate students participated to the experiment on the basis of voluntary agreement. All of them were native Italian speakers and reported normal or corrected-to-normal vision.

Design. The experiment constituted a 2 (SQ: clear vs. degraded) X 2 (Frequency: low vs. high) factorial design, with the two factors manipulated within subjects. All the primes were unrelated to the following targets.

Stimuli. The same targets as in Experiment 1 were used as targets. Primes were the same as well, with the only difference that additional 80 words (40 high frequency and 40 low frequency) were selected to be used as primes for nonwords. In fact, since in Experiment 2 all words were presented with their unrelated primes, there was not the possibility to rotate part of the unrelated primes across words and nonwords. These new primes did not differ from the primes previously selected for nonword targets in terms of frequency, length or orthographic neighborhood density (all ts < 1). Taken together, primes used from nonwords did not differ from the primes used for words for frequency, length or orthographic neighborhood (all *t*s < 1).

Apparatus and procedure. Same as in Experiment 3.

3.3.2 Results

Trials in which an error (3.81%) or a voice-key failure occurred (4.68%) were removed from the analyses. The remaining RTs were submitted to the same recursive data trimming procedure as in Experiment 3, which resulted in the elimination of further 1.52% of the responses. Before running ANOVAs, RTs were transformed into within participant z scores (z-RTs). Mean RTs and proportions of errors as a function of conditions are reported in Table 6, along with the frequency effects.

Table 6. *Mean reaction times (RTs) and mean proportion error (ERR) as a function of context, target frequency and stimulus quality in Experiment 4.*

	Clear			Degraded		
	LF	HF	*FE*	LF	HF	*FE*
RTs	648	615	*33 [23, 43]*	858	813	*45 [30, 60]*
ERR	.02	.00	*.02 [.01, .03]*	.06	.02	*.04[.02, .06]*

Note. LF = low frequency; HF = high frequency; *FE* = frequency effect; *PE* = priming effect. The 95% confidence intervals for the frequency effects are reported within brackets.

Response latencies. The main effects of SQ (F_1 [1, 31] = 201.84, MSE = .141, p < .001; F_2 [1, 158] = 1,857.5, MSE = .038, p < .001), and frequency (F_1 [1, 31] = 69.50, MSE = .019, p < .001; F_2 [1, 158] = 28.41, MSE = .115, p < .001) were significant. The interaction between the two factors was marginally significant in the analyses by subjects

(F_1 [1, 31] = 3.51, MSE = .009, p = .071) while it was not in the analysis by items (F_2 [1, 158] = 2.19, MSE = .038, p > .1).

Accuracy. Significantly more errors are made on words presented in the visually degraded condition with respect to the words presented in the clear condition (F_1 [1, 31] = 20.213, MSE = .001, p < .001; F_2 [1, 158] = 36.882, MSE = .002, p < .001). High frequency words appear to be yield less errors (F_1 [1, 31] = 28.701, MSE = .001, p < .001; F_2 [1, 158] = 21.852, MSE = .002, p < .001). The interaction between SQ and frequency is significant (F_1 [1, 31] = 8.159, MSE = .001, p < .01; F_2 [1, 158] = 7.461, MSE = .002, p < .01): the frequency effects on accuracy is larger when targets are presented in the degraded condition.

Distributional analyses. Contrary to the expected results, data form Experiment 2 are suggesting that frequency and SQ produce an overadditive interaction even when all the primes are unrelated to their targets. It is therefore important to see whether the interaction assumes the same distributional shape as was for Experiment 3, where repeated and unrelated trials were randomly intermixed.

According to the prime reliance account, in the previous experiment, retrospective prime reliance was instantiated. Coherently, the frequency effect for degraded targets was slightly stronger in the slowest quintiles, probably due to the fact that the most difficult targets are hindered by the reliance on an unrelated prime. If a similar pattern is found in the present experiment, this would contradict the prime reliance account. Here, in fact, participants did not have any reason to rely on prime information (similarly to what occurs in Study 1, Experiment 2), and therefore an increase of the frequency effect for the slowest degraded targets is not expected. In other words, to keep the prime reliance account valid, the marginally significant SQ by frequency interaction should be mediated by the fact that the frequency effect is larger for degraded targets, but such a difference is constant all across the distribution and does not increase in the slowest quintiles. Frequency effect as a function of SQ are plotted in Figure 11. Clearly, the difference between the frequency effect detected for clear vs. degraded items is quite stable across the distribution and, crucially, does not seem to get larger in the slowest quintiles.

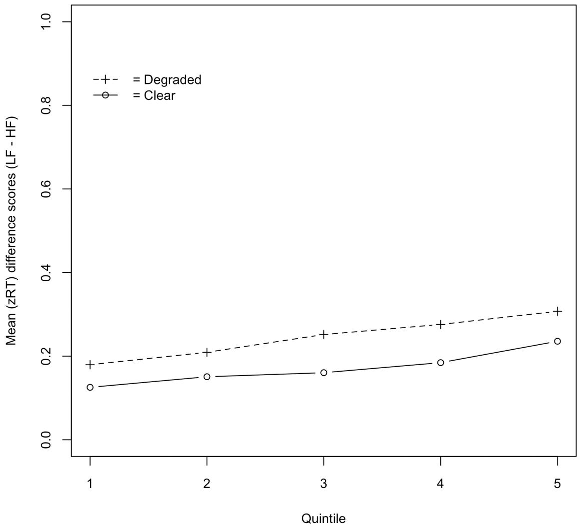

Figure 11. *Experiment 4: Difference in the quintile-means for low frequency versus high frequency words as a function of stimulus. HF = high frequency. LF = low frequency.*

3.3.3 Discussion

Overall, the results from Experiment 4 provided some support to the prime reliance account, but also some undeniable problematic points that deserve attention. Contrary to the predictions, and contrary to what happens in English (e.g., Study 1, Experiment 2; see also O’Malley & Besner, 2008), SQ and frequency produced a marginally significant interaction. Although it’s not fully significant, and not paralleled by a similar result in the analysis by items, it appears to be in contrast with what has been detected in English. The distributional features might shed some light, but it’s worth noting that the reasoning on this issue is speculative and takes place at a descriptive level. Nonetheless, when comparing the distributional features of frequency effect for clear and degraded targets preceded by unrelated prime across the two experiments, some interesting differences seem to be present. More specifically, in Experiment 3 the difference between the frequency effect for clear versus degraded targets seems to get larger as the RTs get slower. On the other hand, in Experiment 4, the difference in the frequency effect between clear and degraded targets appears to be stable across the distribution: It seems quite similar for fastest, modal and slowest RTs. I would argue that in Experiment 3 we have a trace of retrospective prime reliance, but not in Experiment 4. As such the marginal interaction detected in Experiment 4 might have a different nature, which possibly involves cross-linguistic differences. These aspects are discussed in more detail in the general discussion.

3.4 General discussion

According to the framework outlined in the previous chapter, retrospective prime reliance is signaled by (a) an increase of the priming effect at the slowest RTs for degraded targets (b) an increase of the frequency effect detected in the slowest responses to degraded targets when these are preceded by unrelated primes. Experiment 3 provided results that seem to fit, at least partially, with the framework. The SQ by frequency interaction detected on targets preceded by unrelated primes is paralleled by an increase of the priming effect for slowest responses to degraded targets. Moreover, a slight increase of the frequency effect is detected for the slowest responses to degraded words preceded by unrelated primes.

On the other hand, Experiment 4 has shown that, even in a context where retrospective prime reliance cannot be at play, a marginal SQ by frequency interaction is found. Clearly, this result is at odds with the prime reliance account. However, when considering the distributional features of the SQ by frequency interaction, some intriguing differences between the two experiments emerged. More specifically, the marginal SQ by frequency interaction in Experiment 4 is not paralleled by an increase of the frequency effect for the slowest responses to degraded targets compared to clear ones: Indeed, the difference in the frequency effect for clear and degraded words appears quite stable and equal all across the distribution. This is coherent with the fact that no prime reliance is instantiated in Experiment 4: There is no evidence that unrelated primes are hindering the slowest low frequency targets. Moreover it might suggest that the SQ by frequency interaction in Experiment 3 is *partially* and not *solely* mediated by retrospective reliance on prime information (as suggested both by the lack of a significant SQ by frequency by quintile interaction and by the presence of a SQ by frequency interaction since earliest quintiles in unrelated trials). This might stem from the fact that, even if retrospective prime reliance is instantiated, unrelated primes might not be so hindering in a repetition priming paradigm: mismatch between prime and target can be easily detected and -hence- retrospective reliance on prime information might be interrupted earlier compared to what happens in a semantic priming paradigm. In other words, retrospective reliance on primes might just contribute to the overadditive interaction between frequency and SQ detected in unrelated trials of Experiment 3, but it's not a necessary element to produce such a pattern of effects. In fact, the overadditive interaction -although weaker- is found even when participants are not engaged in retrospective prime reliance (Experiment 4). However, it's important to note that in this second case the interaction assumes a slightly different distributional shape, i.e., slowest responses for degraded targets offer no discernable contribution to the interaction, which, in turn, is constant across quintiles.

Even if the reader accepts this admittedly tentative explanation, he/she might still be righteously puzzled by the cross-linguistic discrepancies highlighted by the comparison of the results obtained in Experiment 4 and the ones obtained by Experiment 2 (Study 1). In other words, why intermixing word and nonword targets in English produces additive effects of SQ and frequency in English (O'Malley & Besner, 2008), but not in Italian?

Before considering the issue, it’s worth outlining the principal features of dual route models (Coltheart et al., 2001; Perry et al., 2007), a framework in which these issues have been largely discussed. In doing so, I will take into account just the DRC model (Coltheart et al., 2001), since the CPD+ model (Perry et al., 2007) is more a hybrid between a dual route model with localized lexical representations and a PDP model for the sublexical route. The DRC model implements a dual-route architecture consisting in a lexical and in a sublexical (or nonlexical) pathway. Earlier levels of processing, such as visual features extraction and letter processing, are shared by the two routes. Also, the output from the two pathways converge in the same phonemic buffer. Words in the lexical pathway are represented as localized units within the orthographic input lexicon and the phonological output lexical. Basically, activation from the letter-level is fed to the lexical representation in the orthographic lexicon and then to the corresponding representations in the phonological lexicon. Finally, activation reaches the phonemic buffer, in which the phonemes included in the stimulus get activated. Note that activation flows in a cascaded fashion: This means that processing at a given level does not need to be completed before activation is forwarded onto the next level. In contrast, as soon as activation starts rising at a given level, it is immediately forwarded onto the next one. Moreover, interactive-activation is implemented between the letter-level and the orthographic lexicon, between the orthographic and the phonological lexicon and between the phonological lexicon and the phonemic buffer. Critically, the lexical route can pronounce all regular and irregular words represented in the lexicons, but is unable to deliver a correct pronunciation for nonwords (i.e., letter strings that do not have corresponding representation in the lexicons). On the other hand, following activation at letter level, the sublexical route converts orthographic sublexical units (i.e., graphemes) to phonemes in a serial fashion, from left to right. Of course, this route is able to read nonwords but assigns just regular pronunciations during the grapheme to phoneme conversions. Therefore, the sublexical pathway is unable to correctly read aloud words with an irregular pronunciation. Finally, it's worth noting that these two routes operate in parallel, even though the lexical route is faster then the sublexical one.

How can we interpret the ambiguous results from Experiment 4 within this framework? Let's start considering the case of English. According to O'Malley and Besner (2008), degraded nonwords are particularly prone to lexicalization errors: Degraded nonwords that closely resemble real words can be erroneously identified as those real words they resemble. In order to avoid this kind of mistake, the system assumes a thresholded functioning. In other words, activation is not forwarded to lexical representations until the ambiguity produced by degradation is resolved at lower processing levels (letter processing). In fact, if lexical entries are activated before visual ambiguity is resolved, they might unduly fill the ambiguous visual pattern via top-down pathway. What makes Italian different with respect to these dynamics? I would like to argue that such difference lies in the consistency of the orthography-to-phonology mapping. Italian, with this respect, is a transparent language. In a dual-route framework (e.g., Coltheart et al., 2001), when confronted with degraded targets the Italian-speaking participants might just increase their reliance on the sublexical pathway. This would avoid (or reduce the likelihood of) lexicalization errors, without recurring to a thresholded function of the earlier levels of the system. Note that the idea that reliance on the sublexical pathway is increased when nonwords are intermixed with words in the target set of a pronunciation experiment is not new and has already been proposed in the literature (e.g., Job, Peressotti, & Cusinato, 1998; Paap & Noel, 1991; but see also Lupker, Brown, & Colombo, 1997). Regarding the specific issue of what happens in terms of the joint effect of SQ and frequency when nonwords are intermixed with words in a pronunciation task, Ziegler, Perry, and Zorzi (2009) claimed precisely that, in presence of nonword stimuli, the output of the sublexical pathway is emphasized, with respect to the lexical one.

This claim has not been unchallenged. O'Malley and Besner (2009) indeed noted that altering the balance between the lexical and the sublexical pathway in current dual route models is a delicate issue. In fact, when emphasizing output from the sublexical pathway, the models produce a number of regularization errors that are not seen in human participants. The reason is straightforward: In a highly irregular language such as English, the output of a sublexical grapheme-to-phoneme conversion and the one of a lexical pathway often diverge. If output from the sublexical pathway is emphasized, this would lead to regularization errors, because the lexical pathway cannot intervene and assign the correct pronunciation to irregular words. In Italian, however, this might not be the case. In fact, given the regularity of the grapheme-to-phoneme mapping, the sublexical pathway would reliably produce a correct output. In this scenario, increasing the reliance on the sublexical grapheme-to-phoneme conversion route would not increase the chance to produce errors. In this situation, there is no need for the system to strategically implement a thresholding of the letter level in order to relegate the effect of SQ to earlier levels of processing. In other words, the system would keep its cascaded activation unmodified. Note that, in a fully cascaded system, an increased reliance on the sublexical pathway does not imply that the lexical one is totally shut down. Lexical representations in the orthographic input lexicon and in the phonological output lexicon might still influence processing, even though their influence would be mitigated. If that is the case, assuming that the system is flexible and that increased reliance on the sublexical pathway would be at play only for degraded targets, reduced frequency effect when words and nonwords are intermixed can be expected together with a hint of an overadditive interaction between SQ and frequency (particularly, as was the case for present experiments, when the effect of visual degradation is strong thus leaving more time for any lexical influence to emerge).

Finally, it's worth spending few lines discussing the idea that repetition priming might entail retrospective processing, which clearly appears as a counterintuitive idea. At first glance, in fact, presenting as a prime the very same word as the target intuitively sounds like the prototypical case of prospective priming, where the prime pre-activates the target's lexical entry. There's nothing in the presented data that rules out this reasoning and indeed there is no need to. Prospective and retrospective mechanism can in fact co-exist (e.g., Balota et al., 2008). The first would reflect, in terms of distributional analysis, in a shift of the distribution, while the latter would reflect into an increased priming effect in the slowest tail. As can be seen in Figure 8, both these features are found in Experiment 3. Note that the prime reliance account makes strong predictions on these issues. More specifically, it predicts that an increased priming effect at the slowest RTs is paralleled by an increased frequency effect for the slowest degraded words, which contributes to the overadditive SQ by frequency interaction detected for unrelated trials at the level of analyses of the means. The experimental data reported in the present study approached this theoretical pattern. In conclusion, I would argue that the data presented in this second study suggest that a retrospective mechanism is instantiated even for the repetition priming, as long as we accept the assumption that increased priming effect in the slowest tail of RTs distribution is a product of increased retrospective prime reliance.

CHAPTER IV. STUDY 3: RETROSPECTIVE PRIME RELIANCE AND MEMORY

4.1 Introduction

What processes does a retrospective reliance on prime entails? As previously argued (Chapter II), findings in the prime reliance framework are in line with the theoretical perspective advocated by Bodner and Masson (2001; 2003; 2004; for a review, see Masson & Bodner, 2003) in recent years. These two authors have proposed a unified account for both masked and standard priming that relies on retrospective retrieval of prime information. The basic idea is that the prime is encoded as an episodic memory resource that is later recruited to aid target identification. The concept that priming might entail an episodic retrieval at SOA as short as 200 ms (as in Experiments presented in previous chapters) at first glance sounds counterintuitive. Actually, Bodner & Masson have claimed that such a retrieval occurs even in masked priming paradigm, where typically primes are exposed for durations below 60 ms and masked, with the result that participants are not consciously aware of the occurrence of primes. Such a "radical" perspective (Masson & Bodner, 2003) indeed stems from a very interesting and thought-provoking framework, which is clearly at odds with respect to more popular activation accounts. Note that such a mechanism would not reflect conscious recollection, but rather automatic influences of memory traces on task performance. Actually, in this perspective word recognition is conceived as retrieval from a large population of memories of prior similar episodes and such a sampling of memories regarding prior episodes is not accompanied by conscious recollection (Masson & Bodner, 2003; see also Jacoby, 1983; Koler & Roediger, 1984).

As acknowledged by Masson and Bodner (2003), this perspective was suggested by Whittlesea and Jacoby's (1990) seminal work. These authors, using a three event priming paradigm, found that the RTs to a target word (e.g., DANCE) presented as the third stimulus was more influenced by a repetition prime (e.g., DANCE) when an interpolated related word was degraded (e.g., WaLtZ), compared to when it was not (e.g., WALTZ). The idea is that the degraded interpolated word increases the emphasis on retrieving the first word (Balota et al., 2008) thus producing larger repetition priming effect of this first word on the final target. In other words, having an interpolated degraded word triggers prime retrieval and, as a consequence, the prime word results more available when it's time to process the target-word (third word), increasing the repetition priming effect. Clearly, participants cannot foresee whether the interpolated word would be degraded or not, and it is difficult to explain the differential use of the first word as a function of the degradation of the second word in terms of a purely prospective account.

Balota and colleagues (2008) considered this retrospective episodic retrieval as the mechanism underlying the SQ by semantic priming interaction: when target degradation hinders bottom-up processing, the system retrospectively recruit the prime as a source of information to identify the target. Episodic retrieval might indeed be the mechanism that mediates such a prime recruitment. The following experiments were specifically designed to address this issue, that is, whether episodic retrieval is involved in retrospective prime reliance. To test this hypothesis, during the first phase of the experiment participants performed a lexical decision task, where SQ and semantic prime relatedness were manipulated. When this phase was finished, after a brief distracter task in which they had to judge the correctness of simple mathematical equations, they performed a recognition test. Half of the words presented during the recognition test were words that were not displayed during the lexical decision task (foils). The other half were the prime that preceded the targets during lexical decision. The idea is that, if participants use episodic retrieval of the primes preceding degraded targets during lexical decision, one might expect a higher recognition performance for those primes that preceded the degraded targets compared to the ones preceding clearly visible targets. In other words, given that the primes that have been previously retrieved (during lexical decision), they would benefit of a facilitated retrieval later in the memory task.

In this scenario, different predictions can be drawn. First, intuitively one would predict to observe a relatedness effect even during the memory task: Primes that were related to the targets should be recognized better, compared to those displayed with an unrelated target. From the one hand, related pairs might produce stronger memory traces due to their distinctiveness. On the other hand, related pairs might entail a deeper processing and this would lead to better recognition due to increased depth of processing for stimuli presented within related pairs. For the prime reliance account, however, it's more important to assess whether participants will have better recognition for those primes that, during lexical decision, preceded degraded targets. The most straightforward prediction would be that, both for related and unrelated pairs, those primes that preceded degraded targets in lexical decision are better recognized afterwards. This prediction stems from the fact that, in previous experiments, evidences for prime retrieval have also been found for unrelated pairs. The reliance on prime information occurring even for unrelated pairs, in fact, is what produced the SQ by frequency interaction detected for unrelated trials in Experiment 1 and what magnified the same interaction in Experiment 3. Consequently, if episodic retrieval is the mechanism mediating prime reliance, one would expect increased recognition for primes that preceded degraded targets, irrespective of the fact that these were semantically related or not. On the other hand, we do not know and we do not have yet, I think, any principled reason to say that unrelated and related primes undergo the same processes. The evidences presented here seems to suggest that they are both involved in retrospective recruitment of prime information, but we do not know what happens next. For example, after being retrieved, it might be the case that related primes reduce the amount of activation needed to recognize the target (Thomas et al., 2012) or that related primes and corresponding targets form compound cues (Racliff & McKoon, 1988; Whittlesea & Jacoby, 1990). Further, it is not clear what happens to unrelated primes after being recruited. Of course, it seems that their recruitment hinders processing for most difficult targets (Experiment 1 and 3), but it's unclear what happens next. Arguably, the system needs to discard these primes, otherwise they would continue to produce incoherent evidence and to hinder target processing. Representations of these unrelated primes might be inhibited or actively discarded, and this might have consequences on the ability to recognize them later on in the memory task.

Summing up, I would conclude that the prime reliance account articulated as a mechanism of episodic retrieval predicts that related primes preceding degraded targets in lexical decision will be better recognized compared to related primes that preceded clearly visible targets. As for unrelated primes, it's an empirical issue to assess whether the eventual episodic retrieval will outweigh the subsequent relinquishment of the prime, thus leading to better recognition for primes preceding degraded targets even in the unrelated condition, or whether the two opposing processes will wash each other out, thus leading to a recognition rate that it's comparable to those primes that preceded clear targets. Finally, there's even the possibility that discarding the unrelated primes during lexical decision outweigh the episodic-retrieval component, thus lowering the ability to recognize those primes: this would reflect into a lower recognition rate of unrelated primes that preceded degraded words compared to those unrelated primes that preceded clear targets.

4.2 Experiment 5

4.2.1 Method

Participants. Thirty-two undergraduates students of Washington University in St. Louis participated to this experiment, in exchange of course credits or compensation ($10).

All of them were native English-speakers and reported normal or corrected-to-normal vision.

Stimuli. Eighty prime-target pairs were selected from the Nelson, McEvoy, and Schreiber (1998) norms. Unrelated pairs were created by randomly reassigning primes to targets. Eighty pronounceable nonwords were selected from the English Lexicon Projects Database (Balota et al., 2007). Words and nonwords did not significantly differ in length, orthographic neighborhood, summed and mean bigram frequencies. Eighty words were selected as primes for nonwords and were not different from the primes used for words on frequency, length, orthographic neighborhood, mean and summed bigram frequencies. Finally, 80 words were selected to be used as foils during the recognition test, and these were not different from primes used for words in terms of raw and log-transformed frequency, orthographic and phonological neighborhood and summed and mean bigram frequencies. Prime relatedness and SQ were counterbalanced across subjects, such that each target appeared equally often in all conditions across participants and no word or nonword was repeated within a participant.

Proprieties of the materials used are listed in Table 7. All variables were taken from the English Lexicon Project Database (Balota et al., 2007), except for backward and forward association strength that were taken from the Nelson, McEvoy, and Schreiber (1998) norms.

Apparatus and procedure. Participants were tested in a dimly-lighted testing-room, with a maximum of 6 participants running at the same time. Each participant was seated at a distance of approximately 40 cm. from the computer's monitor in individual stations. Each station was isolated from the flanking ones with separator-screens that prevented light coming from other monitors to reach the participant and -possibly- interfere. Data were collected on Pentium 4 computers using E-Prime 1.1 (Schneider et al., 2001).

Table 7. *Properties of the items used in Experiment 5*

	Words	Nonwords	t_{lex}	Foils	t_{rec}
Primes					
Length	5.29	5.16	-.47	5.15	.47
Frequency	35560.91	30067.61	-.58	28376.09	.70
Log frequency	9.41	9.33	-.29	9.21	.77
Orth. N	4.95	5.40	.52	5.49	-.60
Phon. N	10.63	11.26	.39	11.28	-.36
Sum Bigram	7886.51	7508.53	-.47	7616.6	.31
Mean Bigram	1701.29	1776.55	.60	1781.84	-.66
Targets					
Length	5.21	5.16	-.23	-	-
Frequency	36338.2	-	-	-	-
Log frequency	9.35	-	-	-	-
Orth. N	5.04	4.91	-.15	-	-
Sum Bigram	7831.24	7326.23	-.89	-	-
Mean Bigram	1820.79	1862.94	.35	-	-
FAS	.56	-	-	-	-
BAS	.57	-	-	-	-

Note. Orth. N = orthographic neighbourhood. Phon. N = phonological neighbourhood. FAS = forward association strength. BAS = backward association strength. t_{lex} = t values generated from an independent samples t-test between items belonging to the nonword group versus items belonging to the word group. t_{rec} = t values generated from an independent samples t-test between primes paired with word targets versus foils presented in the recognition task. All the t-values are not significant (all *p*s > .3).

The experiment was divided into three phases, each one with a different task. Participants knew that they would perform three different tasks, but the tasks were not described in advance. The first phase consisted in a lexical decision task. In each trial, a fixation point (+) was displayed for 1000 ms., followed by a prime (in lower-case) which remained on the screen for 150 ms. After a blank screen of 750 ms, the target (in uppercase) appeared and remained on the screen until participants gave their responses or, in case no response was given, until 5000 ms have elapsed. The inter-trial interval was 1000 ms, and consisted in a blank screen. The letter strings were displayed in 18-point Courier New font on a black background (Red, Green, Blue [RGB] 0, 0, 0). In the bright condition, targets were presented in RGB (120, 120, 120); in the dim condition, they appeared in RGB (12, 12, 12). Primes and the fixation point were always presented in the bright RGB (120, 120, 120). Participants were instructed to mentally read the prime and to perform a lexical decision on the target, by pressing "A" or "L" on the keyboards (responses were counterbalanced across participants, so that half of them had to respond "A" for word-responses and "L" for nonword-responses, while the other half did the opposite). A set of 16 practice-trials (8 words and 8 nonwords) preceded the experimental session. For practice word-trials, SQ and prime relatedness were manipulated (2 trials per condition). Practice nonword-trials consisted of 4 word-primed clear nonwords, and 4 word-primed degraded nonwords. Primes and targets (words and nonwords) used in the practice session were never presented in the experimental phase.

After the lexical decision, participants entered the second phase, in which they were asked to judge whether simple equations (e.g., 11 + 12 = 23) presented on the screen were correct (by pressing the "Y" key) or incorrect (by pressing the "N" key). The task lasted one minute.

The third phase consisted in a recognition task. Single words were presented at the center of the screen, and participants were instructed to press "O" when they thought that the word on the screen was one of the primes they previously saw during lexical decision (old items) or "N" when they thought that the word on the screen was a new word, which was never presented during lexical decision. Instruction were kept on the screen across the whole test, and participants were informed that half of the words were the primes they saw in lexical decision, while the other half consisted in new items that were not previously displayed (foils). Words stayed on the screen until a response was given. When a response was detected, the following item was immediately displayed. Primes and foils were presented randomly intermixed, with different full-random sequences for each participants.

4.2.2 Results

4.2.2.1 Lexical decision

Response latencies and proportions of correct responses were analyzed across participants and items, thus yielding to F_1 and F_2 statistics respectively. Prime-target semantic relatedness and SQ were within-participant factors both for the analyses by participants and the ones by-items.

Trials with incorrect responses (6 %) were not considered for analyses of response times. The remaining data were submitted to a recursive data-trimming procedure (Van Selst & Jolicœur, 1994) that resulted in the removal of a further 3.39 % of the data, considered as outliers. Response times were then transformed into within-participants z-scores (z-RTs).

Mean response latencies and mean percent errors as a function of condition are displayed in Table 8.

Table 8. *Mean reaction times (RTs) and mean proportion errors (ERR) as a function of context and stimulus quality in Experiment 5.*

	Clear			Degraded		
	Unrelated	Related	*PE*	Unrelated	Related	*PE*
RTs	613	578	35 [14,56]	841	738	103 [77,129]
ERR	.04	.01	.03[.01,.05]	.11	.06	.05[.02,.08]

Note. *PE* = priming effect. The 95% confidence intervals for the priming effects are reported within brackets.

Response latencies. The main effect of SQ was significant (F_1 [1, 31] = 2299.83, MSE = .033, $p < .001$; F_2 [1, 79] = 3359.45, MSE = .055, $p < .001$), as was the one of prime semantic relatedness (F_1 [1, 31] = 4.58, MSE = .018, $p < .05$; F_2 [1, 79] = 6.26, MSE = .036, $p < .05$). The interaction was significant as well (F_1 [1, 31] = 17.72, MSE = .019, $p < .001$; F_2 [1, 79] = 22.65, MSE = .038, $p < .001$).

Accuracy. The ANOVA on proportion of correct responses yielded significant main effects of SQ (F_1 [1, 31] = 10.40, MSE = .01, $p < .01$; F_2 [1, 79] = 58.22, MSE = .004, $p < .001$) and of semantic relatedness (F_1 [1, 31] = 15.72, MSE = .003, $p < .001$; F_2 [1, 79] = 15.70, MSE = .007, $p < .001$), while the interaction did not reach significance (F_1 [1, 31] = 1.76, MSE = .002, $p > .19$; F_2 [1, 79] = 1.52, MSE = .007, $p > .2$)

Distributional analyses. Mean priming effects for clear and degraded targets as a function of quintile are plotted in Figure 12. As can be seen, for clear targets the effect is quite the same all across the distribution and decreases abruptly in the last quintile, for degraded targets it increases disproportionally for slowest responses.

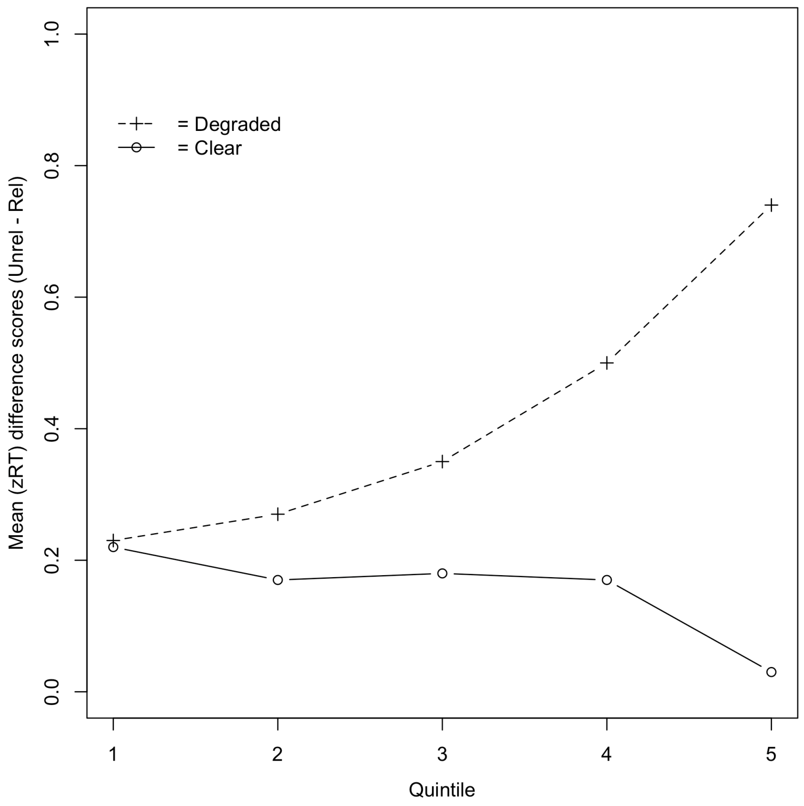

Figure 12. *Difference in the quintile-means for unrelated (Unrel) versus related (Rel) words as a function of stimulus quality*

In the lexical decision task, the two key results were successfully replicated: Priming and SQ produce an overadditive interaction, which is particularly emphasized in slowest response times. As such, the experiment offers a pattern consistent with the retrospective prime reliance account (Balota et al., 2008; Thomas et al., 2012). It's important now to consider findings from the recognition test, in order to assess whether any evidence consistent with episodic recruitment emerges.

4.2.2.2 Recognition test

Analyses of variance were conducted both on hit rates and d' measures. Hit rates were analyzed across both participants and items, thus yielding, respectively, F_1 and F_2

statistics. Mean hit rates and d' as a function of experimental condition are plotted in Figure 13.

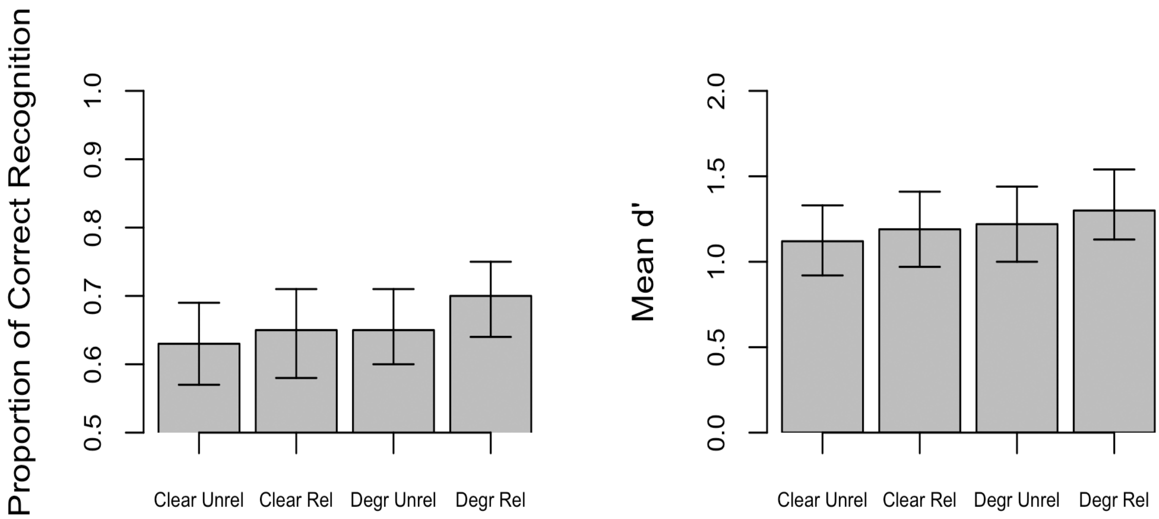

Figure 13. *Mean proportion of correct recognition (hits) and mean d' for primes as a function of semantic relatedness (Rel = Related, Unrel = Unrelated) and SQ (Degr = Degraded) of the target. Error bars represents mean standard errors.*

For hit rates, the main effect of SQ was marginally significant in the by-participant analysis (F_1 [1,31] = 3.23, MSE = .013, p = .08), and reached significance in the analysis by item (F_2 [1, 79] = 4.9, MSE = .022, p < .05). The effect of semantic relatedness was significant in the by-participant analysis (F_1 [1, 31] = 4.49, MSE = .007, p < .05), but only marginally significant in the by-item analysis (F_2 [1, 79] = 3.11, MSE = .023, p = .08). The interaction did not reach significance (Fs < 1).

For d', the main effect of SQ was marginally significant (F [1, 31] = 3.54, MSE = .131, p = .07), as was the effect of semantic relatedness (F [1, 31] = 3.68, MSE = .071, p = .06). The interaction did not reach significance (F < 1).

4.2.3 Discussion

Overall, results from Experiment 5 do not offer a clear cut evidence in favor of episodic retrieval as the mechanism underlying retrospective prime reliance. The lexical decision task offered the prototypical set of findings that have been discussed in terms of retrospective prime reliance: The overadditive SQ by priming interaction is strongly mediated by slowest responses, in which the priming effect for degraded trials is increased, as opposed to what happens for clearly visible words. In a later recognition test, however, the effects of relatedness and SQ were just marginally significant both when considering proportion of correct recognitions and d' measures (even though the effect of SQ reached significance in the by-items analysis on hit rates). On the other hand, the direction of the effects matches the predictions: recognition is better for primes that preceded a semantically related prime and for primes that preceded degraded targets. Given the absence of any hint of interaction, moreover, it seems that if an episodic retrieval is truly occurring during lexical decision, this is not affected by the semantic relationship between prime and target. This is consistent with the idea that, although related and unrelated primes are highly likely to undergo different processing after episodic retrieval has occurred, this further processing does not seem to override the previous episodic component. In other words, even though it seems reasonable to assume that the retrieved unrelated prime has to be discarded at a certain point during target processing, this process does not seem to obscure the eventual episodic trace, otherwise at least a direction towards an interaction should have been found: The effect of SQ should have been detected just on primes that were previously presented before semantically related targets.

At this point, however, results are not strong enough to attempt any definitive conclusion. In the next experiment, an attempt was made to replicate these findings in a different language (i.e., Italian). Note that, as currently shaped, the hypothesis driving the present study has no reason to predict cross-linguistic differences. Provided that evidences for retrospective retrieval are found in a lexical decision task using Italian language, if such a mechanism relies on episodic retrieval, predictions are the same as the ones formulated for English-speaking participants. In this second experiment, moreover, memory for primes that preceded nonwords in lexical decision was also tested.

4.3 Experiment 6

4.3.1 Method

Participants. Thirty-three undergraduate students of the University of Padova participated to the experiment on the basis of voluntary agreement. All of them were native Italian-speaker and reported normal or corrected-to-normal vision.

Stimuli. Eighty prime-target pairs were selected from the Nelson, McEvoy, and Schreiber (1998) norms, and then translated into Italian. Care was taken in order to select pairs that are likely to be associated even in Italian (e.g., *left-right*) and to exclude pairs that might be uncommon in the Italian context (e.g., *baseball-bat*). Unrelated pairs were created by randomly reassigning primes to targets. Eighty nonwords were created by changing a letter or two from a set of eighty words that were not used in the experiment. Words and nonwords were not significantly different in terms of length and neighborhood density. A last set of eighty words was selected to serve as primes for nonword targets. Primes for nonwords were not different from primes selected for words in terms of frequency, length and orthographic neighborhood density. A set of 120 words were selected to be used as foils during the recognition test. Eighty of these foils were used as foils for primes used for word-targets. These eighty foils were not different from the eighty words used as primes for words in terms of frequency, length and orthographic neighborhood frequency. The other 40 foils were used as foils for those primes that preceded nonword-targets in lexical decision, and these two groups were not different in terms of frequency, length and orthographic neighborhood. Note that, within each participant, only a subset consisting in 40 of the primes that preceded nonword targets (20 of those primes that preceded clear nonwords, 20 that preceded degraded nonwords) were tested in the recognition phase, given that only a single variable was manipulated for these primes (i.e., visual quality of the targets). Proprieties of all items are listed in Table 9.

Table 9. *Properties of the items used in Experiment 6*

	Words	Nonwords	t_{lex}	Word Foils	$t_{\text{rec-word}}$	NW Foils	$t_{\text{rec-nw}}$
Primes							
Length	6.43	6.41	.04	6.44	-.04	6.55	-.37
Frequency	129.27	130.85	-.04	117.09	.35	142.65	-.24
Orth. N	6.14	5.99	.15	5.76	.39	5.55	.39
Targets							
Length	6.43	6.43	.00	-	-	-	-
Frequency	116.55	-	-	-	-	-	-
Orth. N	4.94	5.04	-.13	-	-	-	-
FAS	.64	-	-	-	-	-	-
BAS	.51	-	-	-	-	-	-

Note. Orth. N = orthographic neighborhood. FAS = forward association strength. BAS = backward association strength. Frequency values were retrieved from the Colfis database (Laudanna et al., 1995) and then transformed into number of occurrences on 1 million t_{lex} = t values generated from an independent samples t-test between items belonging to the word group versus items belonging to the nonword group. $t_{\text{rec-words}}$ = t values generated from an independent samples t-test between primes for word targets versus correspondent foils presented in the recognition task. $t_{\text{rec-nw}}$ = t values generated from an independent samples t-test between primes for nonword targets versus correspondent foils presented in the recognition task.

In the lexical decision phase of the experiment, Prime relatedness and SQ were counterbalanced across subjects, such that each target appeared equally often in all conditions across participants and no word or nonword was repeated within a participant. The set of primes preceding nonword targets in lexical decision that was presented during the recognition test was counterbalanced across subjects, so that all the primes for nonword targets appeared equally often across participants during recognition.

Apparatus and procedure. Participants were tested individually in a dimly lit room, seated at a distance of approximately 40 cm. from a FLATRON F700B monitor. Vocal responses triggered, via an ATR 20 microphone (Audio-Technica), a serial response box (Psychology Software Tools). The experimental procedure and data collection were controlled by a Pentium 4 computer running E-Prime 1.1 (Schneider, Eschman, & Zuccolotto, 2001).

For the lexical decision task, the procedure was exactly the same as in Experiment 5. The only difference consisted in the RGB values used to manipulate visual quality, given the different screen used in the present experiment. In the bright condition, targets were presented in RGB (75, 75, 75); in the dim condition, they appeared in RGB (7, 7, 7). A set of 16 practice-trials (8 words and 8 nonwords) preceded the experimental session. For practice word-trials, SQ and prime relatedness were manipulated. Practice nonword-trials consisted of 4 word-primed clear nonwords, and 4 word-primed degraded nonwords. Stimuli used in the practice session were not presented in the experimental phase. The second phase consisted again in a task, lasting one minute, in which participants were asked to judge whether simple equations (e.g., 11 + 12 = 23) presented on the screen were correct (by pressing the "S" key) or incorrect (by pressing the "N" key).

The third phase consisted in the recognition task previously described, and the procedure was the same as in Experiment 5. As in the previous experiment, single words were presented at the center of the screen, and participants were instructed to press "S" when they thought that the word on the screen was one of the primes they previously saw during lexical decision or "N" when they thought that the word on the screen was a new word, which was never presented during lexical decision.

4.3.2 Results

4.3.2.1 Lexical decision

Response latencies and proportions of correct responses were analyzed across participants and items, thus yielding to F_1 and F_2 statistics respectively. Semantic relatedness and SQ were within-participant factors both for the analyses by participants and by-items.

Trials in which a wrong response was given (4 %) were not considered for analyses of response times. The remaining data were submitted to a recursive data-trimming procedure (Van Selst & Jolicœur, 1994) that resulted in the removal of a further 2.87 % of the data, considered as outliers. Response times were then transformed into within-participants z-scores (z-RTs). Mean response latencies and mean percent errors as a function of condition are displayed in Table 10.

Table 10. *Mean reaction times (RTs) and mean proportion errors (ERR) as a function of context and stimulus quality in Experiment 5.*

	Clear			Degraded		
	Unrelated	Related	*PE*	Unrelated	Related	*PE*
RTs	669	591	78 [58,98]	848	721	127[100,154]
ERR	.02	.01	.01[.00,.02]	.07	.04	.03[.01,.05]

Note. *PE* = priming effect. The 95% confidence intervals for the priming effects are reported within brackets.

Response latencies. When considering word targets, the main effect of SQ was significant (F_1 [1, 32] = 168.47., MSE = .08, p < .001; F_2 [1, 79] = 505.67, MSE = .065, p < .001), as was the one of prime semantic relatedness (F_1 [1, 32] = 175.41, MSE = .032, p < .001; F_2 [1, 79] = 176.02, MSE = .079, p < .001). The interaction was significant as well (F_1 [1, 32] = 8.92, MSE = .036, p < .01; F_2 [1, 79] = 13.72, MSE = .055, p < .001). When considering word (in unrelated trials only) and nonwords, the main effect of SQ was again significant (F_1 [1, 32] = 227.82, MSE = .091, p < .001; F_2 [1, 158] = 746.20, MSE = .067, p < .001). The effect of lexicality was significant (F_1 [1, 32] = 247.62, MSE = .065, p < .001; F_2 [1, 158] = 141.09, MSE = .292, p < .001) with nonwords yielding longer latencies. The SQ by lexicality interaction did not reach significance in the analysis by participants (F_1 [1, 32] = 2.37, MSE = .041, p >.1), while approached significance in the analysis by items (F_2 [1, 158] = 3.13, MSE = .067, p < .1).

Accuracy. When considering word-targets only, the ANOVA on proportion of correct responses yielded significant main effects of SQ (F_1 [1, 32] = 22.4, MSE = .002, p < .001; F_2 [1, 79] = 31.24, MSE = .003, p < .001) and semantic relatedness (F_1 [1, 32] = 10.68, MSE = .002, p < .001; F_2 [1, 79] = 9.46, MSE = .005, p < .01), while the interaction did not reach significance (F_1 [1, 32] = 1.49, MSE = .001, p > .2; F_2 [1, 79] = 1.45, MSE = .003, p > .2). When considering words (unrelated trials only) and nonwords, the main effects of SQ was significant (F1 [1, 32] = 6.76, MSE = .002, p < .05; F2 [1, 158] = 8.02, MSE = .004, p < .01), while the main effect of lexicality was not (Fs < 1). The interaction between SQ and lexicality was significant (F [1, 32] = 14.66, MSE = .001, p < .01; F2 [1, 158] = 13.22, MSE = .004, p < .001), reflecting the fact that the lexicality effect was significant for clear items (F1 [1, 32] = 9.35, MSE = .002, p < .01; F2 [1, 158] = 11.99, MSE = .004, p < .01), where words yielded higher accuracy compared to nonwords, but not for degraded ones (F1 [1, 32] = 2.67, MSE = .002, p > .1; F2 [1, 158] = 1.7, MSE = .006, p < .1), where actually nonwords yielded numerically higher accuracies.

Distributional analyses. Mean priming effects for clear and degraded targets as a function of quintile are plotted in Figure 14. For degraded targets, we can observe the usual increase of the priming effect for the slowest response times, even if the pattern does not appears as strong as in previous experiments. As expected, the priming effect for clear items does not appear to increase at all in the slowest quintiles, compared to the fastest ones.

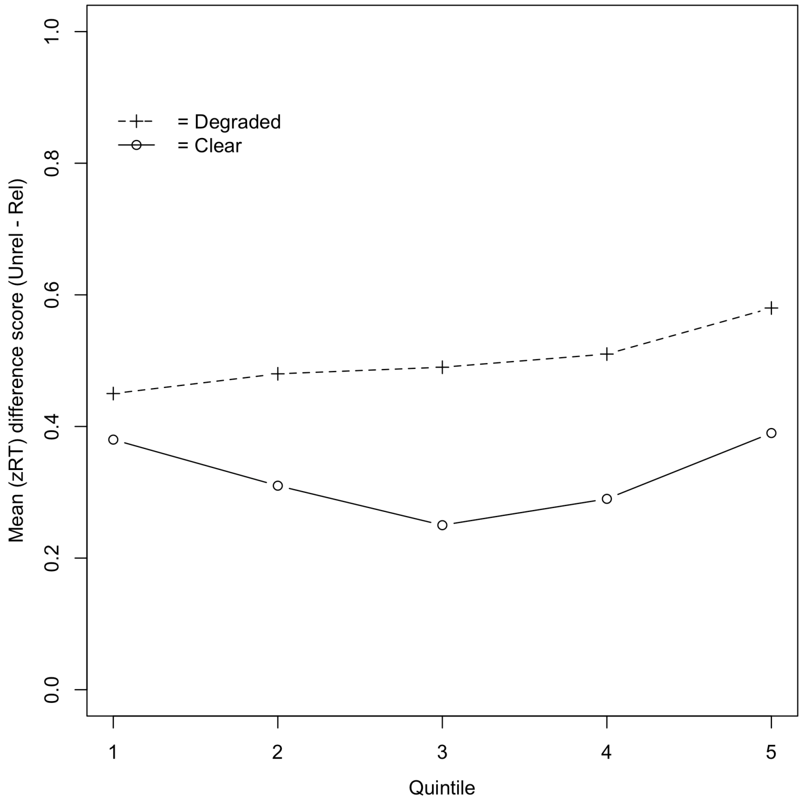

Figure 14. *Difference in the quintile-means for unrelated versus related words as a function of stimulus quality*

4.3.2.2 Recognition test

Analyses of variance were conducted both on hit rates and d' measures. First, primes that preceded words were considered by themselves, in order to assess how targets visual quality and prime-target semantic relatedness during lexical decision affected the recognition test. Mean hit rates and d' as a function of these experimental conditions are plotted in Figure 15. As a second step, primes that preceded unrelated words were compared with those primes that preceded nonword targets in lexical decision, in order to evaluate the effect of lexicality and its eventual interaction with target visual quality. These results, in terms of mean hit rate and mean d’ as a function of condition, are plotted in Figure 16. For both analyses, hit rates were analyzed across participants and items, thus yielding, respectively, F1 and F2 statistics.

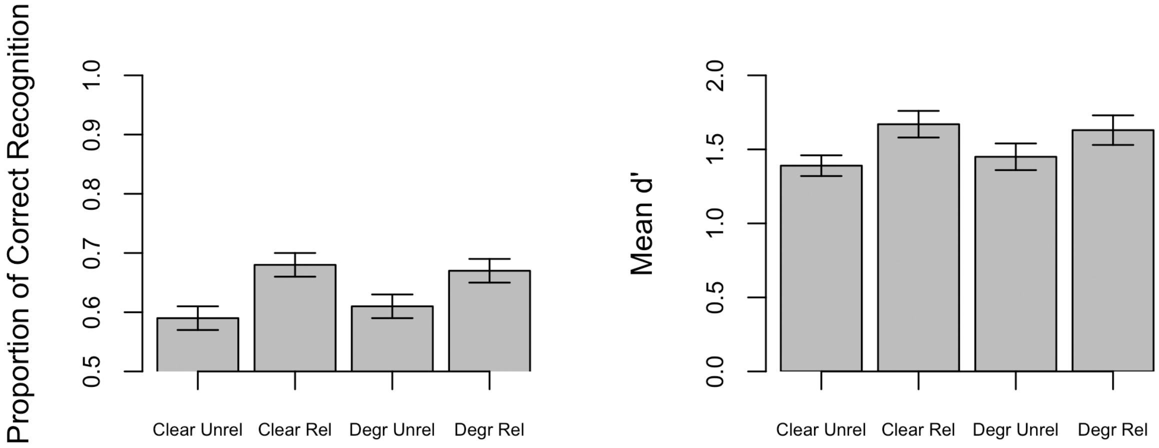

Figure 15. *Mean proportion of correct recognitions (hits) and mean d’ for primes that were paired with word-targets during lexical decision as a function of semantic relatedness (Rel = Related, Unrel = Unrelated) and SQ (Degr = Degraded) of the target. Error bars represent mean standard errors.*

When considering just those primes that preceded word-targets during lexical decision task, hit rates showed only a main effect of semantic relatedness (F_1 [1, 32] = 22.49, MSE = .009, p < .001; F_2 [1, 79] = 18.28, MSE = .028, p < .001): those primes that were presented before a semantically related targets in lexical decision were recognized more accurately. Nor the effect of SQ (Fs < 1), neither the SQ by semantic relatedness interaction (F_1 [1, 32] = 1.11, MSE = .008, p > .1; F_2 < 1) were significant. Analyses on d’ measures paralleled the results obtained for hit rates, with the significant effect of semantic relatedness (F [1, 32] = 21.33, MSE = .083, $p < .001$), no effect of SQ ($F < 1$), and no interaction (F [1, 32] = 1.32, MSE = .072, p >. 2).

As clearly appears from previous analyses, the present experiment was not able to replicate the trend towards an effect of SQ that was observed in Experiment 5. A reason for this might be the difference in the materials used. In Experiment 6, 42 out of the total 80 prime-target pairs were antinomies (e.g., *left-right*), as opposed to Experiment 5, in which only 26 out of the total 80 pairs were antinomies. This might have biased the participants of the present experiment to adopt a different strategy during the recognition task. More specifically, when presented with the prime, they might have retrieved the target as well by simply generating its opposite. This would produce a benefit by adding a further memory resource to guide the task. In other words, when participants are presented with the prime, even if they do not remember it, nor the correspondent target, they might just generate the latter and use this representation to aid prime recognition. This leads to the prediction that, among those primes that were presented in the related condition during lexical decision, antinomies (e.g., *left-right*) should yield better recognition compared to other pairs that do not constitute an antinomy (e.g., *thunder-lightening*), irrespective of the visual quality of the target.

When considering antinomy as a factor amongst the other variables, it resulted to exert a significant effect on the proportion of correct recognition in the analysis by participants (F_1 [1, 32] = 7.05, MSE = .028, $p < .05$) but not in the one by items (F_2 [1, 78] = 2.41, MSE = .1, p >.1). Coherently with the predictions, the three way interaction between SQ, semantic relatedness, and antinomy was not significant (*F*s < 1). Contrary to the predictions, even the relatedness by antinomy interaction failed to reach significance on hit rates (F_1 [1, 32] = 1.87, MSE = .033, $p > .1$; F_2 [1, 78] = 2.41, MSE = .027, $p > .1$). However, when comparing antinomies versus non-antinomies in each condition, a significant effect was found for targets preceded by related primes, both in the clear (t_1 [32] = 2.2, p < .05; t_2 [78] = 2.32, p < .05), and in the degraded condition (t_1 [32] = 2.2, p < .05; t_2 [78] = 1.65, p > .1), with higher hit rates for antinomies. The effect of antinomy, on the other hand, was not significant when primes preceded an unrelated target in lexical decision, and this was true both for clear (t_1 [32] = 1.32, p > .1; t_2 [78] = 1.12, p > .2) and degraded (*t*s < 1) targets.[3]

The experiment gave also the opportunity to assess the role of target lexicality on prime recognition, by comparing recognition performance for those primes that preceded semantically unrelated word targets and those preceding nonword targets (see Figure 16).

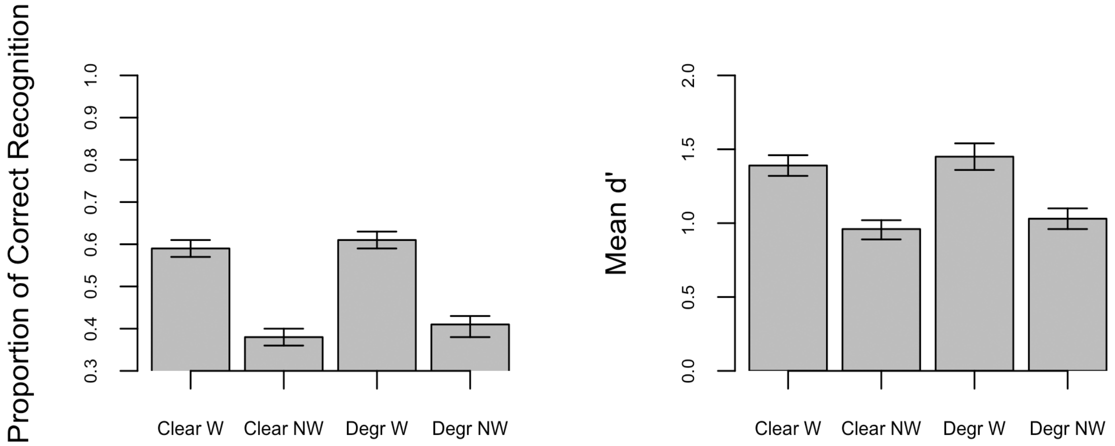

Figure 16. *Mean proportion of correct recognitions (hits) and mean d' for primes as a function of targets' lexicality (W = Word; NW = nonword). Degr = Degraded.*

The main effect of lexicality was significant in terms of hit rates (F1 [1, 32] = 97.25, MSE = .014, p < .001; F2 [1, 118] = 36.52, MSE = .063, p < .001), with primes that preceded word-targets yielding higher accuracies. Lexicality did not interact with SQ (Fs

---

[3] For experiment 5, the effect of antinomy was not significant neither for primes that preceded semantically related clear (t_1 [31] = 1.52, p >.1; t_2 [1, 78] = 1.54, p >.1) or degraded (ts< 1) targets, nor for primes that preceded unrelated clear (ts < 1) or degraded targets (t_1 [31] = -1.37, p > .1; t_2 [78] = -1.26, p > .2).

< 1). Moving to d’ measure, again the effect of lexicality was significant (F1 [1, 32] = 27.19, MSE = .221, p < .001), and there was no interaction with SQ (F < 1).

4.3.3 Discussion

Results from Experiment 6 did not replicate the trend observed in the previous experiment. Indeed, there was no hint of an SQ effect in the memory task. In other words, contrary to the previous experiment, there was no evidence that primes that preceded degraded words in lexical decision were better recognized compared to those primed that preceded visually intact words. As already argued, this might stem from peculiar features of the materials selected in the present experiment: 52.5% of the prime-target pairs were in fact antinomies. Results showed that these antinomies led to better prime recognition, compared to other related pairs, and this was true for both clearly visible and degraded targets to a comparable extent. The hypothesis is that, when participants were presented with the primes during the recognition task and they were not able to recognize them, they might have retrieved the target by simply generating on the fly the prime’s semantic opposite, thus having a second memory resource to aid primes recognition. Clearly, such a mechanism would imply a conscious strategic effort. Indeed, the idea of analyzing the specific pattern of results yielded by antinomies vs. non-antinomies was suggested when a participant, during the debriefing, explained the strategy that he applied during recognition, which was exactly the one I have outlined here. However, this explanation -which is admittedly and entirely post-hoc- appears quite speculative, and the experiment was not specifically designed to address this issue. Nevertheless, it make sense to argue that higher-order strategy might be involved in the recognition task, and -as such- care must be taken during items-selection in order to avoid materials that might bias the adoption of peculiar strategies. These strategies, although operating at a higher level compared to the mechanisms investigated, might nonetheless influence the results, possibly obscuring smallest, lower-level effects.

On the other hand, the present experiment detected a strong effect of targets' lexicality on primes' recognition: Primes that preceded nonword-targets were harder to recognize, compared to those primes that preceded a real -although semantically unrelated-word-target. The explanation of this effect, which appears to make sense intuitively, is not straightforward. Why a prime that was presented before a nonword should produce a weaker memory trace? One reason might lie in the incompatibility of a word prime and a nonword target in terms of the response required in a lexical decision task. More specifically, a word-prime would be coherent with the "word" response required by a word-target. The nonword-targets, on the other hand, requires a "nonword" response: In this case, the word prime (preceding the nonword target) is incoherent with the response required by the target. Of course, we have to assume that such incompatibility in terms of response somehow entails the production of a weaker memory trace for the prime representation. Alternatively, one has to assume that, given equal memory trace for representations of primes preceding word- and nonword-targets, the difference lays in the inhibition occurring for primes preceding nonword-targets. In this scenario, we can hypothesize that, when the target is a nonword, the system needs to discard the lexical activation produced by the prime (which would lead the system to a "word" response), by inhibiting it. It's however quite unlikely that inhibition produced within a given lexical decision trial would last that long, i.e., until the memory task. Clearly, these kind of accounts strongly relies on task-specific operations involved in lexical decision. This predicts that, in a recognition test, no difference should be detected amongst prime preceding word-targets and those preceding nonword-targets when the task in which these are first presented is a speeded pronunciation, as opposed to a lexical decision. In such a scenario, the lexical decision specific operation producing the difference in recognition performances would in fact be absent.

A different account is to hypothesize that a word-target produces stronger memory traces for primes by establishing a lexical context. In other words, the system would make connections between prime and targets, thus producing stronger memory traces even for primes. This is quite similar to the idea underlying compound cues models (e.g., Ratcliff & McKoon, 1988), in which prime and targets are used as a single compound cue to probe memory. However, it's not clear how this would work for unrelated primes preceding word-targets. As seen, these primes yield a much higher proportion of correct recognitions compared to the primes that preceded nonwords, yet it's not clear what would mediate the supposed connections between the primes and their correspondent semantically unrelated word-targets. Obviously, the link does not rely on a semantic dimension, which is the one postulated in compound-cue models. On the other hand, this account predicts the relatedness effect that was indeed detected in Experiment 6: The links between a prime and a semantically related target should be stronger then those between the same prime and a semantically unrelated target. However, as already discussed, the present effect of semantic relatedness might be emphasized by the prevalence of prime-target pairs based on antinomy. Actually, in Experiment 5, only a trend towards a relatedness effect was detected.

4.4 General Discussion

Taken together, the two experiments presented in this chapter did not offer clear-cut evidence supporting the hypothesis that retrospective prime reliance entails episodic retrieval. The basic prediction was, in fact, that the primes preceding degraded targets in lexical decision (i.e., those primes involved in retrospective reliance, see Balota et al., 2008) should be better recognized in a memory task, compared to those primes that preceded visually intact targets. However, only a marginal effect of targets' stimulus quality was detected in Experiment 5, while no hint of the effect was detected in Experiment 6. Of course, it's entirely possible that the paradigm devised here it's not sensitive enough to capture these sorts of effects. For example, memory task such as cued-recall or free recall might prove to be more suited for this kind of investigations. Alternatively, since the hypothesized episodic retrieval of the prime occurring during lexical decision is thought to be unconscious, one might want to test memory for primes with a task that taps more automatic memory process (but see Jacoby, 1991) such as fragments completion. It has to be noted, however, that more subtle effects in Experiment 6, as already argued, might have been obscured by higher order strategies applied in the recognition test.

On the other hand, some other interesting issues were raised by the results of these study. Specifically, a strong effect of target lexicality was found during the prime-recognition task: Primes that have preceded word-targets are recognized better compared to those primes that have preceded nonwords. Hypotheses about the mechanisms underlying this pattern have already been discussed in the previous paragraph: The effect might stem from task-specific operations involved in lexical decision, or from the fact that primes and targets establish connections among each other that strengthen the memory trace for both representations. Clearly, both alternatives need further investigation, for example by testing prime recognition after tasks different from lexical decision (e.g., speeded pronunciation), to rule out task specificities.

Apart from the specific hypotheses that can be formulated to account for the results, the interesting fact, at the present level of specification, might even be the result *per se*. In fact, it suggest that those processes regarded as purely linguistic might indeed entail a link with the memory domain. The idea is not new. Apart from the mentioned efforts from Jacoby (e.g., Jacoby & Dellas, 1981; Jacoby, 1983; Whittlesea & Jacoby, 1990), Ratcliff and McKoon (1988) and Bodner and Masson (e.g., Masson & Bodner, 2003) to outline links between memory and word recognition, also Forster has considered in great detail the issue of an episodic component within repetition effects (Forster & Davis, 1984). However, the strong lexicality effect presented here, moves towards a somewhat different direction. In fact, it suggests that linguistic processing can modulate the “quality” and the strength of the memory traces produced by the materials presented during the linguistic task itself. In other words, the interplay between prime and target during those processes that ultimately lead to the recognition of the latter one might produce different memory traces for both representations. Note that the “depth of processing” framework might not be sufficient to explain the lexicality effect detected here. In fact, if those stimuli that need deeper processing should be better recognized in a subsequent memory task, then one might even expect that the primes preceding nonword-targets would yield to higher hit rates. The system, in fact, might need to actively suppress the representations activated by those primes preceding nonword-targets, given the interference they might exert on the production of the correct response to the lexical decision task. This further operation, of course, would not be required by those primes that precede unrelated word-targets.

Finally, it’s worth mentioning that, in this chapter, findings and theoretical positions in agreement with the idea that retrospective prime reliance entails an episodic component have been widely discussed. However, in the literature, there are also results that challenge this idea. More specifically, Thomas and colleagues (2012) have shown that the SQ by semantic priming interaction is present when prime-target pairs are related via a backward target-to-prime semantic association, but not when they are related via a pure forward prime-to-target association. As appropriately noted by the authors, if retrospective prime reliance (i.e., the mechanism producing the SQ by priming overadditive interaction) is based on episodic retrieval of the prime, and if episodic retrieval can occur even in absence of backward target-to-prime association (i.e., it can occur for forward prime-to-target associated pairs), why prime-target pairs with a forward association do not produce the interaction? In other words, why only those primes that are linked to the target via backward association can be episodically retrieved to aid degraded targets' recognition? Even if assuming that a backward association facilitates prime retrieval, one would have to assume also that episodic retrieval for primes in forward associated pairs is not possible, which is clearly a very unlikely scenario.

CHAPTER V. FINAL DISCUSSION

5.1. Semantic priming and joint effects of stimulus quality and word frequency

The first aim of this thesis was to assess whether a retrospective account for semantic priming effects on visually degraded target (i.e., the retrospective prime reliance account) might explain the complex pattern of effects arising from the joint manipulation of prime-target semantic relatedness, targets' visual quality and targets' frequency. To reiterate, additive effects of stimulus quality and frequency are found on trials where prime and target are semantically related, while the two effects produce an overadditive interaction in those trials in which there is no semantic relationship between prime and target (see Borowsky & Besner, 1993). Two things are worth noting. The first one is that many studies, over a considerable time-span, have investigated the effects of these three variables by considering two of them at the time while, when the experiments presented here were started, just a single published work had manipulated all the three variables within the same experiment (Borowsky & Besner, 1993). The second is that the pattern of effects described above was not explicitly and specifically discussed or analyzed neither in Besner and Borowsky's article, nor in following studies that this seminal and important work has inspired, with the notable exception of Yap and Balota (2007) and Robidoux and colleagues (2010). These authors, in fact, acknowledged and discussed the pattern, although without specifically investigating it. In conclusion, it's interesting to note that this intriguing and relevant pattern of effects has been around, somewhat hidden, for almost 20 years.

Confronted with this theoretically relevant conundrum, the retrospective prime reliance account proved to be able to advance some important predictions. More specifically, the account predicts that the interaction between frequency and visual quality in unrelated trials should be mediated by the slowest response times. In fact, the account hypothesizes that the interaction takes place because reliance on unrelated primes hinders targets' processing, particularly in the case of difficult (i.e., slow, low frequency words) targets. This prediction was confirmed in Experiment 1. Moreover, the account correctly predicts that, in absence of related primes, additive effects of SQ and frequency should be found on unrelated trials (Experiment 2). On a general level, this kind of evidence suggests that the semantic priming paradigm might entail more complex cognitive processes compared to what has been traditionally described. More specifically, other then a purely forward-directed prospective component, which begins as soon as the prime appears, a retrospective process, which starts after target presentation, would be involved. Intriguingly, such a further retrospective process would be invoked to compensate for degraded visual information. In other words, the mechanism would not be present by default, nor would be instantiated irrespective of the specific context: It is likely that this process is invoked only when the payoff is high.

5.2. Further specifications of the prime reliance account and future directions

5.2.1 Retrospective prime reliance in zero-lag repetition priming

The second aim of the thesis consisted in an effort to further specify the retrospective prime reliance account. Assuming that this kind of processing is instantiated in the case of semantic priming, it is in fact interesting to see whether converging evidences of its presence can be found when using a different paradigm, namely zero-lag repetition priming. Probably, when the prime is the same word as the target, purely prospective processes are stronger, compared to when prime and target are different - although semantically related- words. Indeed, there are evidences that the two kind of primes dissociates in an important way. Ferguson, Robidoux, and Besner (2009) have shown that the three-way interaction between stimulus quality, priming, and relatedness proportion (RP), occurs (for speeded pronunciation) just for semantic priming but not for repetition priming. More specifically, when semantic priming is investigated, the interaction between semantic priming and SQ is produced just in presence of a high RP (e.g., 50% of the trials have semantically related prime-target pairs), while the two variables yield a robust additive pattern when the RP is low (see also Stolz & Neely, 1995). On the other hand, repetition priming produces and overadditive interaction with SQ even when RP is low. This might indeed suggest that while the interaction is mediated by some more controlled (and thus context-sensitive) processes in case of semantic priming, in the case of repetition priming is produced by entirely prospective, automatic, bottom-up processes. Given that, in case of semantic priming, interactive effects of SQ and frequency in unrelated trials are thought to occur due to the interference produced by reliance on unrelated (i.e., uninformative) primes, if indeed the SQ by repetition priming interaction is mediated by solely prospective processes, one would expect additive effects of SQ and frequency even after unrelated primes. In a repetition priming experiment, in fact, retrospective reliance might not be at play.

In the present experiments, the presence of a retrospective prime reliance in the context of zero-lag repetition priming was investigated using descriptive distributional analyses. Stronger repetition priming effects were detected in slower quintiles for the degraded condition, and therefore it was concluded that retrospective prime reliance is at play. Is such a conclusion warranted? According to the current level of specification of the theory, I would give a positive answer. Increased semantic priming effects in the slowest tail of RTs distribution for degraded targets are considered as a product of retrospective prime reliance (Balota et al., 2008). Converging evidence for this claim has recently been advanced by Thomas and colleagues (2012), who showed that the increased priming effects in the slowest responses to degraded targets are observed only when prime-target pairs are linked via a component of backward association. Following these arguments, one has to conclude that increased priming effects in the slowest tail of the RTs distribution for degraded targets are a marker of retrospective prime reliance. However, one might still question whether this claim can be extended to repetition priming. It would seem that, if the claim is not valid even for repetition priming, this might represent a major problem for the prime reliance account. If the same phenomenon (the increased priming effect for degraded targets in the slower tail) needs different explanation in different paradigms, the strength of any of these explanations would be importantly diminished.

Other then the SQ by repetition priming interaction mediated by slower RTs, the experiments presented in Study 2 provided just some preliminary further evidence that retrospective prime reliance might be entailed even in a zero-lag repetition priming paradigm. As suggested by the first study, retrospective reliance on unrelated primes can hinder targets' processing, particularly in the case of low frequency words. Such an effect is revealed by the increased frequency effect detected in the slowest tail of the responses given to degraded targets (while for clear ones, the frequency effect is constant across the distribution). This pattern was present, at least at a descriptive level, even in the second study, where repetition priming was used. Note, however, that the idea to assess the presence of retrospective prime reliance by considering its influence in the case of unrelated primes, might not be the most straightforward way, at least in repetition priming. In fact, in a repetition priming paradigm the detection of a mismatch between prime and target can be fast, arguably faster then in a semantic priming paradigm. As such, one might imagine that unrelated primes are more easily and more quickly discarded in a repetition priming paradigm. This, of course, would diminish their (detrimental) influence on target processing.

Another way to test whether retrospective prime reliance is at work even in a repetition priming paradigm, would be to manipulate SQ and repetition priming along with RP. As already demonstrated by Ferguson and colleagues (2009), the SQ by repetition priming is preserved even with low RP. However, if lowering RP imply that retrospective reliance is ceased, this should reflect on distributional features of the priming effect: More specifically, no increase of the priming effect should be detected in the slower tail for responses to degraded target, when the RP is low, while the opposite should be true in case of high RP. In other words, the difference in repetition priming effects for clear and degraded targets (i.e., the SQ by repetition priming interaction) should be constant across all quantiles when RP is low, while it should increase in the slower tail when RP is high. Again, these arguments rely on the idea that retrospective processing, even in the case of repetition priming, is sensitive to RP manipulation. It might not be the case: Given the fact that any eventual mismatch between prime and target can be easily and quickly determined in a repetition priming paradigm (where a related prime is the same word as the target), retrospective retrieval might not be so detrimental even in case of unrelated primes, since these can be easily identified and discarded without having a strong impairment on target processing. If that is the case, the system might even adopt a different strategy, by enabling retrospective prime processing by default, irrespective of relatedness proportion, given the small cost that retrospective reliance might have in terms of the cognitive resources needed, as well as in terms of the interference generated by reliance on unrelated primes. As it is clear, the issue of retrospective prime reliance in repetition priming needs more empirical investigation, but data collected in Study 2 give some preliminary evidence that the mechanism might be at play in this paradigm as well.

Another issue raised by the results of the second study concerns how the presence of nonwords influences reading in a transparent language such as Italian. In English, frequency and SQ produce an overadditive interaction in speeded pronunciation tasks where targets are real words (O'Malley & Besner, 2008; Yap & Balota, 2007) while the same variables yield a robust additive pattern when nonword-targets are randomly intermixed with words (O'Malley & Besner, 2008). Note that additive effects are found in lexical decision as well, where nonwords are present by definition (e.g., Yap & Balota, 2007). O'Malley and Besner (2008) provided a unified account to explain the presence of the additive pattern in tasks where nonword targets are presented along with word targets. The idea is that, in order to prevent lexicalization errors, the system strategically blocks cascaded activation and adopts a more serial organization in activation dynamics. More precisely, in presence of nonwords, the system would not forward activation to lexical representations until activation at the letter-level of processing has reached a certain criterion. This means that no lexical representation is contacted before the detrimental effect of SQ is resolved in earlier levels of processing. Hence, no interaction of SQ and frequency (a lexical variable) is expected.

An alternative idea is that having nonwords in the target set simply leads the system to emphasize the output from the sublexical route (e.g., Ziegler et al., 2009: see also Job et al., 1998; Paap & Noel, 1991; Reynolds & Besner, 2008; Zevin & Balota, 2000). Besner and O'Malley (2009) by assessing simulations reported by Ziegler and colleagues (2009), showed that such a modification produce a number of errors (particularly regularization errors) that is much higher compared to what is found in empirical data. Indeed, altering the balance between lexical and sublexical route in dual route computational models is a very delicate issue (Coltheart et al., 2001). Emphasis on sublexical grapheme to phoneme conversion in a highly irregular language such as English produces many regularization errors because the sublexical route simply maps graphemes to their regular pronunciation. It is the lexical route that recognizes words as specific units, thereby assigning them their correct irregular pronunciation. However, in a transparent language such as Italian the picture might be different: Emphasis can be placed on the output of the sublexical route without the risk of regularization errors. Results from Experiment 4, indeed, show that SQ and frequency yield an ovveradditive interaction, albeit smaller and just marginally significant, in a pronunciation task in which words and nonwords are presented as targets.

This might not be relevant just to understand Italian language, but English as well. Consider the case in which it will be proved that for lexical decision results are the same across the two languages, i.e., SQ and frequency, when manipulated in lexical decision, produce additive effects both in Italian and in English. Clearly this would undermine the idea that the additive pattern is a product of the same mechanism (i.e., thresholding the letter-level of processing) in lexical decision and pronunciation, since it would be evident that, even in a language where such thresholding does not take place, lexical decision still produces additive effects.[4] An explanation of the additive pattern found in lexical decision might be related to the specificities of this task. Yap and Balota (2007) suggested that additive effects of frequency and SQ in lexical decision are due to the reliance on familiarity-based decision (see also Balota & Chumbley, 1983). In this framework, familiarity refers to a “multidimensional quantity that reflects the orthographic and phonological similarity of a letter string to real words” (Yap & Balota, 2007, p. 276). In this perspective, visual degradation hinders familiarity-based information in the stimuli, thereby requiring that degraded targets undergo a perceptual normalization during the early encoding stage. Note that the account is not completely different from O’Malley and Besner’s (2008) idea that, in presence of nonwords, visual degradation needs to be resolved in earlier stage, before any contact with lexical representation, in order to avoid lexicalization errors. The main difference lays in the reasons of such a reclusion of the visual degradation effect in earlier stages. According to Yap and Balota (2007), this is due to task-specificities, namely the reliance on familiarity-based information in the lexical decision task. Clearly, to extend this perspective to speeded pronunciation, one needs to make the somewhat paradoxical assumption that familiarity-based information become relevant even in this latter task, provided that real words are intermixed with nonwords.

---

[4] Of course, if using Italian language one finds interactive effects of SQ and frequency in lexical decision as well, this would further strengthen O’Malley and Besner’s (2008) argument.

That is, the manipulation of the target-set makes the speeded pronunciation more similar to a lexical decision, possibly requiring that some sort of lexical decision is made before the actual pronunciation. Of course, even this framework predicts that when additive effects of SQ and frequency are found in lexical decision, they should be found also in pronunciation, when words and nonwords are intermixed. If future studies will show that, in Italian, SQ and frequency produce additive effects in lexical decision, but an interaction in pronunciation (irrespective of the presence of nonwords in the targets set) this would represent a major problem for both accounts. In fact, this would stand as an evidence that thresholding is not required by the presence of nonwords (thus contradicting O'Malley and Besner's argument), as well as an evidence that the presence of nonwords does not emphasize familiarity-based decisional processes (thus contradicting the claim that, when nonwords are intermixed with words in a pronunciation task, familiarity-based information is emphasized, similarly to what happens in lexical decision).

5.2.2 Retrospective prime reliance as episodic retrieval

In an effort to explore the cognitive operations involved in retrospective prime reliance, Study 3 explored the possibility that, when confronted with degraded targets, the system enhances its reliance on contextual information (i.e., information given by the prime) via episodic retrieval. Such a proposal was indeed advanced by Balota and colleagues (2008) in their seminal investigations, and is linked to a broad framework that conceptualize priming effects essentially as memory phenomena (e.g., Masson & Bodner, 2003; Whittlesea & Jacoby, 1990). In basic terms, the memory trace for prime-representation is recruited and participates to degraded target identification. The prediction driving Study 3 was that, if such a recruitment takes place during a linguistic task (i.e., lexical decision), it would also reflect in a subsequent memory task (i.e., recognition task). Even though in the predicted direction, the results of this study are quite weak. Marginal effects of stimulus quality were found only in the first empirical investigation (i.e., Experiment 5), in which participants recognized marginally better those primes that preceded degraded targets, compared to the primes preceding clearly visible ones. The attempt to replicate this pattern in a second experiment failed, probably due to higher order strategies triggered by the characteristics of the materials (i.e., most of the prime target pairs were antinomies). This possibility prompts further considerations. For example, one might argue that while (hypothesized) retrieval operations in lexical decision are essentially unconscious and not strategic (e.g., Masson & Bodner, 2003), the memory task is based on controlled and conscious strategies. If that is the case, it might be hard to see consequences of the former into the latter. In other words, the processes at work in the two tasks, although subsumed under the same definition (episodic retrieval), might be very different. Not only higher order strategies involved in conscious retrieval during an explicit recognition task can obscure more subtle effects, but also these kind of processes might be insensitive to similar but unconscious processes executed in previous experimental phases.

Similar questions are not new in studies that investigated memory processes, in which a lot of attention has been directed towards dissociation in memory measures. The prototypical observation driving research in this issue, is that participants can display evidence of learning on some measures even though such learning is not accompanied by conscious recollection of the original learning episode (Blaxton, 1989; see Jacoby & Witherspoon, 1982). One of the most important study in the field was conducted by Jacoby (1983) and it is often taken as a compelling evidence for the dissociation among memory measures (see Blaxton, 1989). In Jacoby's study, during the initial phase of the experiment participants either read aloud or generated target words in one of three different conditions. In the no-context condition, they simply read aloud the target (e.g., *cold*), after being presented with a neutral stimulus (a string of Xs). In the context-condition, again participant read aloud the target, but this time it was preceded by an antonym (e.g., *hot*). Finally, in the generate-condition, participants were asked to generate the target, given the antonym cue. Recognition performances in a subsequent phase showed that participants recognized better those targets presented in the generate-condition, compared both to context- and no context-condition. Moreover, context-condition yielded better recognition performance compared to no context condition. However, when memory for targets was assessed via a perceptual identification task (where participants had to read aloud words displayed for 35 ms.), performances showed the opposite pattern, with higher recognition rates for targets presented in the no context condition, followed by targets presented in the context-condition. Lowest performances were observed for those targets that, in the previous phase, were generated from their antonym.

As noted by Blaxton (1989), two different theoretical accounts have been advanced to address similar dissociations. The first one emphasize differences between memory tasks: While some tasks require to perform an explicit recollection of the original learning episode (e.g., free recall), others do no not (e.g., fragment completion). In Tulving (1972) terms, the former would be an episodic (or explicit) task, while the latter a semantic (or implicit) one. The idea, then, is that different tasks tap different memory systems, with episodic memory involved in explicit tasks, where participants need to overtly think back to a specific episode occurred in the study-phase, and semantic memory involved into implicit tasks, where no explicit reference to a prior episode is requested. In the case of Study 3, this might mean that the lexical decision task and the recognition task are so different, that there’s no reason to expect effects carrying over from the former to the latter. Retrospective prime reliance in lexical decision, in fact, would involve implicit retrieval of prime information, essentially tapping the semantic memory system. On the other hand, recognition performance would clearly involve explicit episodic retrieval, thus tapping the episodic memory system.

A second theoretical account for dissociations between memory measures focuses less on tasks themselves and places stronger emphasis on the cognitive operations performed in the study-phase and the ones performed at test. This theoretical position claims that memory performance would be improved to the extent that operations performed during the study and the test phases overlap. This principle is known as transfer-appropriate processing (Blaxton, 1989). Under this perspective, we have some additional elements to predict that operations involved in lexical decision should reflect into the recognition performance. Recognition performances might be conceived as entailing conceptually driven operations, in which participants rely on analysis of meaning in order to make familiarity decisions (Blaxton, 1989; see also Jacoby, 1991). Similar familiarity-based operations occur in lexical decision as well (e.g., Balota & Chumbley, 1983; see also Balota & Spieler, 1999; Yap & Balota, 2007). In lexical decision, therefore, we can expect that, when confronted with a degraded target the systems retrieves prime representation in order to use it as a cue to probe memory for the target, or to produce a compound-cue with the target (e.g., Whittlesea & Jacoby, 1990; see also Ratcliff & McKoon, 1988). In some sense, in lexical decision participants use the primes as an additional source of information to evaluate target's familiarity. In this scenario, the prime would have a critical role in computing the final familiarity value that drives the response for the target. Similar processes might be at play during the recognition task, where participants have to evaluate the prime representation and express an explicit judgment on its familiarity. In summary, according to this second framework, we can expect better recognition for primes preceding degraded targets to the extent that lexical decision and recognition involve similar conceptually-driven retrieval operations aimed at familiarity-based judgments. Note that Experiment 6 provided some evidence that operations involved in lexical decision reflect into the recognition task, since a strong lexicality effect was detected in the latter task: Those primes that preceded nonwords during lexical decision yielded dramatically lower recognition performances compared to the primes that preceded real words. Indeed, this shows that characteristics of the targets in the lexical decision task can influence the subsequent memory performance for the corresponding primes. Such a consideration strengthens the rationale of the experimental paradigm (i.e., the idea that prime-target relationship in lexical decision and specific features of the target can affect prime recognition in a second experimental phase).

5.3 Conclusions

In conclusion, it seems that the major success for the retrospective prime reliance account is to offer a principled explanation for the joint effects of SQ, frequency and semantic priming while making specific predictions on the distributional shape of these effects. At their current level of specification, purely prospective accounts, such as activation models, do not provide any explanation about the different distributional features of the effects in different conditions. How a prospective account could in fact predict increased semantic priming effect for longer RTs in the case of degraded targets, while predicting a solely μ-mediated effect in the case of clear ones? Moreover, how activation models could account for interactive effects of SQ and frequency in unrelated trials, provided that these are intermixed with related ones, as opposed to the robust additive pattern found when only unrelated primes are presented? Regarding this latter question, as suggested in Study 1, it is indeed possible that semantic priming prompts a more fully interactive and cascaded flow of activation, which would not be necessary (it might be in fact harmful, see O'Malley and Besner, 2008) in a context in which primes are predictably uninformative. But even so, why this complex pattern would be mainly mediated by slower RTs?

Of course, even when limiting our focus to the joint effect of SQ, frequency and semantic priming, the definitive solution is yet to be found (see Masson & Kliegl, 2012, for a similar consideration), and prime reliance does not offer the final answer. Actually, one might even claim that this account makes its additional explanations and specific predictions at the expense of parsimony, i.e., by adding further processing mechanisms. However, it has to be noted that, although for the sake of explanatory easiness the retrospective prime reliance account has been here presented “in opposition” to more traditional activation accounts, there’s no reason to think that the two are incompatible. Interesting suggestions for the integrations of the two frameworks, in fact, have been already proposed (see Yap et al., 2012).

Finally, two main issues regarding retrospective prime reliance have been raised here, and need further investigations to be clarified. The first one is the extension of retrospective prime reliance to other forms of priming, such as zero-lag repetition priming. If increased priming effects in slower RTs for degraded targets are indeed the marker of this retrospective mechanism, and if these are found even in repetition priming, one has to conclude that retrospective reliance is operative even in the case of repetition priming. Further comparisons highlighting differences or similarities between the two priming paradigms might provide useful insights. The second issue regards a better specification of the cognitive operations subsumed by the label of retrospective prime reliance. Here, it has been investigated the possibility that episodic retrieval is indeed the mechanism beside the phenomenon. Although evidences were not clear cut, other efforts in this direction seem to be worthwhile. Clearly, other possibilities are on the table as well. Perhaps increased reliance on primes’ semantic information, in a fully cascaded and interactive system, can be just described as an increased weight of such information within the processing and computational chain that ultimately lead to target recognition. It is however clear that, despite different frameworks can be developed, the issue of flexibility and contextual sensitiveness within the word-recognition system cannot be avoided.

Bibliography

Andrews, S., & Lo, S. (2012). Not all skilled readers have cracked the code: Individual differences in masked form priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*, 152-163.

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal behavior, 22*, 88-104.

Balota, D. A., & Abrams, R. A. (1995). Mental chronometry: Beyond onset latencies in the lexical decision task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1289-1302.

Balota, D . A., Aschenbrenner, A. J., & Yap, M. J. (in press). Additive effects of word frequency and stimulus quality: The influence of trial history and data transformation. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 340-357.

Balota, D. A., & Paul, S. T. (1996). Summation of activation: Evidence from multiple primes that converge and diverge within semantic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 827-845.

Balota, D. A., & Spieler, D. H. (1999). Word Frequency, repetition, and lexicality effects in word recognition: Beyond measures of central tendency. *Journal of Experimental Psychology: General, 128*, 32-55.

Balota, D. A., & Yap, M. J. (2006). Attentional control and flexible lexical processing: Explorations of the magic moment of word recognition. In S. Andrews (Ed.), *From inmarks to ideas: Current issues in lexical processing* (pp. 229-258). Hove, England: Psychology Press.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., … Treiman, R. (2007). The English Lexicon Project. *Behavior Research Methods, 39*, 445-459

Balota, D. A., Yap, M. J., Cortese, M. J., & Watson, J. M. (2008). Beyond mean response latency: Response time distributional analyses of semantic priming. *Journal of Memory and Language, 59*, 495-523.

Becker, C. A. (1979). Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 252-259.

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition, 8*, 493-512.

Becker, C. A., & Killion, T. H. (1977). Interaction of visual and cognitive effects in word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 389-401.

Besner, D. (2006) *Visual language processing and additive effects of multiple factors on timed performance: A challenge for the interactive activation framework?* Available from PsyCrit Web site, http://psycrit.com/

Besner, D., Dennis, I., & Davelaar, E. (1985). Reading without phonology? *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 37*A, 477-491.

Besner, D., O'Malley, S., & Robidoux, S. (2010). On the joint effects of stimulus quality, regularity, and lexicality when reading aloud: New challenges. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 750-764.

Besner, D., & Smith, M. C. (1992). Models of visual word recognition: When obscuring the stimulus yields a clearer view. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 468-482.

Besner, D., Wartak, S., & Robidoux, S. (2008). Constraints on computational models of basic processes in reading. *Journal of Experimental Psychology: Human Perception & Performance, 34*, 242-250.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 657-668.

Bodner, G. E., & Masson, M. E. J. (1997). Masked repetition priming of words and nonwords: Evidence for a nonlexical basis of priming. *Journal of Memory and Language, 37*, 268-293.

Bodner, G. E., & Masson, M. E. J. (2001). Prime validity affects masked repetition priming: Evidence for an episodic resource account of priming. *Journal of Memory and Language, 45*, 616-647.

Bodner, G. E., & Masson, M. E. J. (2003). Beyond spreading activation: An influence of relatedness proportion on masked semantic priming. *Psychonomic Bulletin & Review, 10*, 645-652

Bodner, G. E., & Masson, M. E. J. (2004). Beyond binary judgments: Prime Validity modulates masked repetition priming in the naming task. *Memory and Cognition, 32*, 1-11.

Borowsky, R., & Besner, D. (1993). Visual word recognition: a multistage activation model. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 4*, 813-840.

Borowsky, R., & Besner, D. (2006). Parallel distributed processing and lexical-semantic effects in visual word recognition: Are a few stages necessary? *Psychological Review, 113*, 181-194.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review, 82*, 407-428.

Collins, A. M., & Quillan, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior, 8*, 240-247.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108*, 204-256.

Faust, M. E., Balota, D. A., Spieler, D. H., & Ferraro, F. R. (1999). Individual differences in information processing rate and amount: Implication for group differences in response latency. *Psychological Bulletin, 125*, 777-799.

Ferguson, R., Robidoux, S., & Besner, D. (2009). Reading aloud: Evidence for contextual control over lexical activation. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 499-507.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 680-698.

Holender, D. (1986). Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: A survey and appraisal. *The Brain and Behavioral Sciences, 9,* 1-23.

Humphreys, G. W., Besner, D., & Quinlan, P. T. (1988). Even perception and the word repetition effect. *Journal of Experimental Psychology: General, 117,* 51-67

Hutchison, K. A. (2002). The effect of asymmetrical association on positive and negative semantic priming. *Memory & Cognition, 30*, 1263-1276.

Hutchison, K. A., Balota, D. A., Cortese, M. J., & Watson, M. J. (2008). Predicting priming at the item level. *Quarterly Journal of Experimental Psychology, 61*, 1036-1066.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22,* 485-508.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional use of memory. *Journal of Memory and Language, 30*, 513-541.

Jacoby, L. L., & Dellas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 3,* 306-340.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology, 36*, 300-324.

Job, R., Peressotti, F., & Cusinato, A. (1998). Lexical effects in naming pseudowords in shallow orthographies: Further empirical data. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 622-630.

Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin, 96*, 29-44.

Kiefer, M., & Martens, U. (2010). Attentional sensitization of unconscious cognition: Task sets modulate subsequent masked semantic priming. *Journal of Experimental Psychology: General, 139*, 464-489.

Kinoshita, S., Mozer, M. C., & Forster, K. I. (2011). Dynamic adaptation to history of trial difficulty explains the effect of congruency proportion in masked priming. *Journal of Experimental Psychology: General, 140*, 622-636.

Kolers, P. A., & Roediger, H. L., III. (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior, 23,* 425-449.

Koriat, A. (1981). Semantic facilitation in lexical decision as a function of prime-target association. *Memory & Cognition, 9*, 587-598.

Laudanna, A., Thorton, A. M., Brown, G., Burani, C., & Marconi, L. (1995). Un corpus dell'italiano scritto contemporaneo dalla parte del ricevente. In S. Bolasco, L. Lebart, and A. Salem III (Eds.), *Giornate Internazionali di Analisi Statistica dei Dati Testuali, Vol. I* (pp. 103-109). Roma: Cisu, Lupker, S. J., & Pexman, P. M. (2010). Making things difficult in lexical decision: The impact of pseudohomophones and transposed-letter nonwords on frequency and semantic priming effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 1267-1289.

Lupker, S. J., Brown, P., & Colombo, L. (1997). Strategic control in a naming task: Changing routes or changing deadlines? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 570-590.

Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology, 15*, 197-237.

Masson, M. E. J., & Bodner, G. E. (2003). A retrospective view of masked priming: Toward a unified account of masked and long-term repetition priming. In S. Kinoshita & S. Lupker (Eds.), *Masked priming: The state of the art* (pp. 57-94). New York: Psychology Press.

Masson, M. E. J., & Kliegl, R. (2012). Modulation of additive and interactive effects in lexical decision by trial history. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Advance online publication. doi: 10.1037/a0029180

McClelland, J. L. (1979). On the time relations of mental processes: An examination of systems of processes in cascade. *Psychological Review, 86*, 287-330.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part I. An account of basic findings. *Psychological Review, 88*, 375-407.

McNamara, T. P. (2005). *Semantic priming: Perspectives from memory and word recognition*. New York: Psychology Press

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227-234.

Meyer, D. E., Schvaneveldt, R. W., & Ruddy, M. G. (1975). Loci of contextual effects on visual word recognition. In P. M. A. Rabbit & S. Dornic (Eds.), *Attention and performance V* (pp. 98-118). San Diego: Academic Press.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*, 165-178.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106*, 226-254.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 236-264). Hillsdale, NJ: Erlbaum.

Neely, J. H., & Keefe, D. E. (1989). Semantic context effects on visual word processing: A hybrid prospective-retrospective processing theory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 24, pp. 207-248). New York: Academic Press.

Neely, J. H., Keefe, D. E., & Ross, K. (1989). Semantic priming in the lexical decision task: Roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 1003-1019.

Neely, J. H., O'Connor, P. A., & Calabrese, G. (2010). Fast trial pacing in a lexical decision task reveals a decay of automatic semantic activation. *Acta Psychologica, 133*, 127-136.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). *The University of Florida word association, rhyme and word fragment norms*, Available from http://w3.usf.edu/FreeAssociation/

O’Malley, S., & Besner, D. (2008). Reading aloud: Qualitative differences in the relation between stimulus quality and word frequency as a function of context. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 1400-1411.

O’ Malley, S., Reynolds, M. G., & Besner, D. (2007). Qualitative differences between the joint effects of stimulus quality and word frequency in reading aloud and lexical decision: Extension to Yap and Balota (2007). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*, 451-458.

Paap, K. R., & Noel, R. W. (1991). Dual route models of print to sound: Still a good horse race. *Psychological Research, 53*, 13-24.

Peressotti, F., Pesciarelli, F., Mulatti, C., & Dell’Acqua, R. (2012). Event-related potentials evidence for two functionally dissociable sources of semantic effects in the attentional blink. *PLoS ONE 7(11):* e49099.

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP+ model of reading aloud. *Psychological Review, 114*, 273-315.

Pohl, C., Kiesel, A., & Kunde, W. (2010). Early and late selection in unconscious information processing. *Journal of Experimental Psychology: Human Perception and Performance*, 36, 268–285.

Plaut, D. C., & Booth, J. R. (2000). Individual and developmental differences in semantic priming: Empirical and computational support for a single-mechanism account of lexical processing. *Psychological Review, 107*, 786-823.

Plaut, D. C., & Booth, J. R. (2006). More modeling but still no stages: Reply to Borowsky and Besner. *Psychological Review, 113*, 196-200.

Plourde, C. E., & Besner, D. (1997). On the locus of the word frequency effect in visual word recognition. *Canadian Journal of Experimental Psychology, 51*, 181-194

Posner, M. J., & Snyder, C. R. R. (1975a). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V*, New York: Academic Press.

Posner, M. J., & Snyder, C. R. R. (1975b). Attention and cognitive control. In R. Solso (Ed.), *Information processing and cognition: The Loyala symposium*. Hillsdale, NJ: Earlbaum.

Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review, 85*, 59-108

Ratcliff, R. (1979). Group reaction time distributions and an analysis of distribution statistics. *Psychological Review, 86*, 446-461.

Ratcliff, R., Gomez, P., & McKoon, G. (2004). A diffusion model account of the lexical decision task. *Psychological Review, 111*, 159-182.

Ratcliff, R., & McKoon, G. (1988). A retrieval theory of priming in memory. *Psychological Review, 95*, 385-408.

Reynolds, M. G., & Besner, D. (2004). Neighborhood density, word frequency, and spelling-sound regularity effects in naming: Similarities and differences between skilled readers and dual route cascaded computational model. *Canadian Journal of Experimental Psychology, 58*, 13-31.

Reynolds, M. G., & Besner, D. (2005). Contextual control over lexical and sublexical routines when reading English aloud. *Psychonomic Bulletin & Review, 12*, 113-118.

Reynolds, M. G., & Besner, D. (2008). Contextual effects on reading aloud: Evidence for pathway control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 50-64.

Robidoux, S., Stolz, J. A., & Besner, D. (2010). Visual word recognition: Evidence for global and local control over semantic feedback. *Journal of Experimental Psychology: Human Perception and Performance, 36*, 689-703

Scarborough, D. L., Cortese, C., Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 1-17.

Schneider, W., Eschman, A., & Zuccolotto, A. (2001). *E-prime user's guide*. Pittsburgh: Psychology Software Tool, Inc.

Stanners, R. F., Jastrzembski, J. E., & Westbrook, A. (1975). Frequency and visual quality in a word-nonword classification task. *Journal of Verbal Learning and Verbal Behavior, 14*, 259-264.

Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research, Quarterly*, 16, 32-71.

Stanovich, K. E., & West, R. F. (1979). Mechanism of sentence context effects in reading: Automatic activation and conscious attention. *Memory & Cognition, 7*, 77-85.

Stanovich, K. E., & West, R. F. (1981). The effect of sentence context on ongoing word recognition: test of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 658-651.

Stanovich, K. E., & West, R. F. (1983). On priming by a sentence context. *Journal of Experimental Psychology: General, 112*, 1-36.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica, 30*, 276-315.

Stone, G. O., & Van Order, G. C., (1992). Resolving empirical inconsistencies concerning priming, frequency, and nonword foils in lexical decision. *Language & Speech, 35*, 295-324.

Stolz, J. A., & Besner, D. (1998). Levels of representation in visual word recognition: A dissociation between morphological and semantic processing. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 1642-1655

Stolz, J. A., & Neely, J. H. (1995). When target degradation does and does not enhance semantic context effects in word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 596-611.

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior, 18*, 645-659.

Thomas, M. A., Neely, J. H., & O'Connor, P. (2012). When word identification gets tough, retrospective semantic processing comes to rescue. *Journal of Memory and Language, 66*, 623-643.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). New York: Academic Press.

Vachon, F., & Jolicœur, P. (2011). Impaired semantic processing during task-set switching: Evidence from the N400 in rapid serial visual presentation. *Psychophysiology*, 48, 102–111.

Van den Bussche, E., Van den Noortgate, W., Reynvoet, B. (2009). Mechanisms of masked priming: A meta-analysis. *Psychological Bulletin, 135*, 452-477.

Van Selst, M., & Jolicœur, P. (1994). A solution to the effect of sample size on outlier elimination. *The Quarterly Journal of Experimental Psychology, 47*A, 631-650.

Vincent, S. B. (1912). The function of vibrissae in the behavior of the white rat. *Behavioral Monographs, 1*, 1-84.

Whittlesea, B. W., & Jacoby, L. L. (1990). Interaction of prime repetition with visual degradation: Is priming a retrieval phenomenon? *Journal of Memory and Language, 29*, 546-565.

Yap, M. J., & Balota, D. A. (2007). Additive and interactive effects on response time distributions in visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*, 274-296.

Yap, M. J., Balota, D. A., & Tan, S. E. (2012). Additive and interactive effects in semantic priming: Isolating lexical and decision processes in the lexical decision task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Advanced online publication. doi:10.1037/a0028520

Yap, M. J, Balota, D. A., Tse, C. S., & Besner, D. (2008). On the additive effects of stimulus quality and word frequency in lexical decision: Evidence for opposing interactive influences revealed by RT distributional analyses. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 495-513.

Yap, M. J., Tse, C. S., & Balota, D. A. (2009). Individual differences in the joint effects of semantic priming and word frequency revealed by RT distributional analyses: The role of lexical integrity. *Journal of Memory and Language, 61*, 303-325.

Zevin, J. D., & Balota, D. A. (2000). Priming and attentional control of lexical and sublexical pathways during naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 121-135.

Ziegler, J. C., Perry, C., & Zorzi, M. (2009). Additive and interactive effects of stimulus degradation: No challenge for CDP+: Comment on O' Malley and Besner (2008). *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*, 306-316.