The Nature of the Suppression Mechanism in Reading: Insights from an L1-L2 Comparison

Linet Frey (lf236@cam.ac.uk)
Research Centre for English and Applied Linguistics, 9 West Road
Cambridge CB3 9DP United Kingdom

Abstract

According to the Structure Building Theory (Gernsbacher, 1990), comprehension is understood as a process of building mental representations. Gernsbacher and Faust (1991) suggested that central to this process is the general cognitive mechanism of suppression, the efficiency of which is responsible for individual differences in comprehension skill. Poor comprehenders have an inefficient suppression mechanism due to which they are unable to inhibit irrelevant information. This would cause shifting more often in structure building and constructing smaller and less coherent representational structures. The present paper argues that poor comprehenders’ difficulties in ignoring irrelevant information could reflect a more general problem of controlling information in working memory. Inefficient suppression could be due to inefficiency of some other processes, which drain resources e.g. inefficient decoding. The study reported here looked at suppression of contextually irrelevant meanings of homonyms in L1 vs. fluent L2 using Gernsbacher and Faust (1991) homonym task. The results suggest immediate meaning activation in both L1 and L2, but delayed suppression of irrelevant meanings in L2 with respect to L1. This could mean that suppression in L2 is compromised by less efficient processing elsewhere in the system, or by low quality of lexical representations.

Keywords: inhibition; L2 reading; lexical ambiguity; individual differences.

Introduction

Crucial to any type of coherent cognitive function is the ability to ignore potential interference or inhibit distractor processing in order to focus on stimuli that are relevant to the task at hand (Lavie, 2005). Inhibitory accounts have been proposed in various cognitive domains from visio-spatial orienting to long-term memory retrieval. In language processing, empirical evidence has established the importance of inhibition (i.e. the ability to suppress active but irrelevant information) in many comprehension processes such as lexical disambiguation, syntactic parsing or metaphor comprehension. Not much research has been done into the nature of the inhibitory mechanism in language comprehension, however, or how it relates to other processes and cognitive resources involved in complex cognitive skills such as reading - decoding efficiency or working memory capacity, for example. It is not clear to what extent inhibition is to be understood as a domain general or a domain specific function, an automatic or a controlled process. This is an important point though as it has implications for language teaching.

Automaticity and Control in Reading

Reading skill models fall into two distinguishable groups: theories that attribute reading skill to the degree of automatization of the word-reading processes (e.g. Perfetti, 1985) and suppression models. The former are based on resource theory (e.g. Kahneman, 1973) assuming that there are limited processing resources available to the cognitive system, and these resources are shared by the different tasks. Perfetti (1985) formulated a verbal efficiency hypothesis, which suggests that fast word decoding is crucial for skilled reading as it frees up limited resources for higher-level processes. Poor readers have not fully automatized their word-reading processes, and these low-level processes use up too much of the limited resources leaving too little resources for higher-level processes such as sentence and discourse comprehension.

Any type of skilled performance is often associated with automaticity. Meiran (1996) argues, however, that “attributing reading ability only to the degree of automatization rests on the false premise that automatic and skilled performance are synonymous”. Although automatic processes are effortless and unconscious, they are also described as involuntary, which means that such processing cannot be fully suppressed and its outputs are hard to ignore. The classic example of automaticity of word reading is the Stroop task where subjects are asked to ignore the meaning, and name the ink colour of words, some of which are colour words incongruent with their ink colour. The Stroop effect i.e. interference from incongruent colour words, evident in slower response times demonstrates that automatic processes have the cost of being uncontrollable.

Although automaticity is important, skilled performance also involves control. Rafal and Henik (1994) argue that control of processing, manifested in “the ability to ignore a word or inhibit its processing” when it is necessary for the task, is an important aspect of skilled reading. They suggest that the ability to control reading would be manifested in a reduced Stroop effect and hypothesise that skilled readers should show less of a Stroop effect than unskilled readers. Developmental studies indeed show that the effect first increases and then decreases with increasing age and reading experience. This is explained by word reading becoming automatic gradually and, when certain proficiency is achieved, this automaticity may be reduced subject to will. Dempster (1992) suggests that one of the hallmarks of developmental change in cognitive processes is an increase through childhood in the efficiency of inhibitory processes,
while the reversal of this trend is believed to underline cognitive decline in old age. Although both automaticity and control are clearly important, “the more advanced phase of skilled performance is not automaticity but control” (Rafal & Henik, 1994).

Suppression theories of reading skill are based on the notion of control of activation. In the framework of Structure Building Theory (Gernsbacher, 1990) for example, reading comprehension skill is explained via a model in which inhibition of irrelevant information (suppression) has a crucial role. The theory proposes that comprehenders construct an on-line mental representation of a text by laying a foundation to the mental structure on the basis of first pieces of information, and then linking every incoming proposition to the structure of the mental representation already built. If the incoming piece of information allows for multiple connotations, the contextually irrelevant ones must be quickly deactivated to avoid failing to attach the information to the current representational structure. Such failure would cause forming a new structure and forgetting the old one. The suppression mechanism has a crucial role in this process as it is responsible for decreasing interference caused by contextually irrelevant information so that contextually relevant information could be incorporated into the developing mental structure.

Meiran (1996) suggests a similar model in which “reading ability is related to the speed of dumping activation in system(s) performing low-level analysis of words”.

Lexical ambiguity resolution provides an example of the role of inhibition in language processing. It is generally agreed that interpretation of words is always affected by the sentence, but whether contextual influence occurs only after the semantic information about the word has been accessed in the mental lexicon, or whether it can have an effect even earlier in the process is debatable. However, the bulk of the many studies with ambiguous words have found evidence that all meanings are initially activated (e.g. Swinney, 1979). After exhaustive meaning access, some sort of selection has to take place as only one of the meanings can be integrated into the interpretation. In the framework of Gernsbacher’s Structure Building Theory, this selection is done by lexical, semantic, syntactic, pragmatic and other constraints, which affect the level of activation of different meanings. The theory describes the building blocks of mental structures that comprehenders build as ‘memory nodes’. These nodes are activated by the incoming stimuli and, once activated, they transmit processing signals, which control the structure building process by either enhancing or suppressing other nodes’ activation. Memory nodes are enhanced if the information they represent is necessary for further structure building, and suppressed if it is not (Gernsbacher, 1990). Moreover, ‘suppression and enhancement signals are transmitted as a function of the strength of the activated memory nodes that transmit them’ (Gernsbacher, submitted).

### The Suppression Hypothesis

Gernsbacher, Varner and Faust (1990) found that poor comprehenders lose access to surface information faster than good comprehenders do in visual, auditory and picture stories. They explain the results via claiming that good comprehenders build bigger and more coherent structures, which help to keep more information in a readily available state. Poor comprehenders on the other hand are believed to shift too often in mental structure building producing smaller and less connected representational structures.

Gernsbacher and Faust (1991) carried out a series of experiments to explore why poor comprehenders shift more often in structure building. In one of the experiments they presented subjects with experimental sentences ending in homographs and followed by a target related to the contextually irrelevant meaning of the homograph (1), and control sentences followed by the same target word (2):

1. He dug with a spade   ACE
2. He dug with a shovel   ACE

The subjects’ task was to decide whether the target was related to the sentence. The authors found that poor comprehenders are less able to deactivate irrelevant meanings of homographs. The same pattern of results was found in several other tasks involving inhibiting some types of information in order to concentrate on others: such as suppression of incorrect forms of homophones (e.g. rose when reading rows), typical-but-absent members of visual scenes (e.g. tractor in a farm scene), and information across modalities (e.g. suppressing the activation of related pictures when reading words). On the basis of these findings, Gernsbacher and Faust (1991) propose what will be referred to as the Suppression Hypothesis – namely, that inhibition of contextually irrelevant meanings/connotations/structures plays a central role in the comprehension process, and the efficiency of the general cognitive mechanism of suppression is responsible for individual differences in comprehension skill.

So, poor comprehenders are believed to have an inefficient suppression mechanism due to which they are unable to inhibit irrelevant information. This would cause shifting more often in structure building as this less relevant information remains activated but cannot be mapped onto the developing structure and, thus, may lay the foundation for a new substructure.

### Resource demands

Poor comprehenders’ difficulties in ignoring irrelevant information and their tendency to shift too often do not have to be causally related though. Instead both could reflect a more general problem of controlling information in working memory. Resource theories (e.g. Kahneman, 1973; Navon and Gopher, 1979) assume that there are limited processing resources available to the cognitive system, and these resources are shared by the different tasks. According to this line of thought, it is possible that inefficient inhibition is in
fact due to the inefficiency of some other processes (e.g. inefficient decoding) that drain resources. This relates to Just and Carpenter’s (1992) model of working memory in which the processing and storage components compete for the same pool of resources.

Rosen and Engle (1998) claim that working memory and inhibition are both functions of executive control and propose that the ability to suppress irrelevant information is directly related to working memory capacity. Working memory capacity, however, has been shown to be lower in a person’s L2 than their L1, and the correlation between L1 and L2 working memory increases with increasing L2 proficiency (Walter, 2000). This suggests that inefficient lower level processes in the L2 reduce working memory capacity. The present paper argues, however, that inefficient decoding/meaning retrieval might not just drain resources reducing working memory capacity but it may also reduce resources available to the suppression mechanism itself. This would then increase the tendency to shift too often in the L2 and build less coherent, smaller structures, which would, in turn, impose greater demands on working memory.

The complex links between the different processes would help to explain the phenomenon of L2 reading threshold effect (e.g. Carrell, 1991) whereby people who are skilled comprehenders in their L1 appear to be unable to transfer their L1 reading comprehension skills to L2 until they reach a certain level of proficiency. Walter (2000) suggests that it is the building of mental representations that fails to be transferred in the L2 reading threshold effect. This makes sense if the building of mental representations was crucially dependent on the suppression mechanism and the suppression mechanism shared resources with lower level processes that are potentially less efficient in the L2.

**Domain knowledge- and task effects**

A study by Mcnamara and McDaniel (2004) found a correlation between knowledge of the specific topic of sentence and suppression efficiency. Their experiment provided evidence that regardless of reading skill, subjects with better knowledge of baseball were faster at suppressing contextually inappropriate meanings of homographs in baseball-related sentences, but not in general-topic sentences. Subjects with greater general knowledge, however, were faster at suppressing irrelevant meanings of ambiguous words in general-topic sentences.

In addition to domain knowledge, specific task demands and proficiency may have an effect on inhibition efficiency. Tzelgov, Henik, and Berger (1992) showed that subjects’ expectations can change the patterns of the Stroop effect. They manipulated the proportion of neutral trials (i.e. trials with no colour words) to induce certain expectations, and found that when the proportion of neutral trials was small, subjects were able to reduce the interference effect. The larger the proportion of neutral trials, the greater was the interference effect. Gernsbacher and Faust (1995) also found an effect of task demands showing that suppression of homonyms is susceptible to strategic control. Gernsbacher and Shlesinger (1997) demonstrated variable efficiency in suppression by showing that expertise in simultaneous translation affects the efficiency of suppression during sentence comprehension.

Tzelgov, Henik and Leiser (1990) studied inhibition of word reading in fluent bilinguals in order to determine the influence of language proficiency on inhibitory and facilitatory aspects of the Stroop effect. They manipulated the expected language and congruency in two separate groups of bilinguals with reverse patterns of preferred language. In one session the ratio of stimuli in one or the other language was 80% and 20%, the second session had the reversed proportion of trials. It was found that subjects were able to inhibit the Stroop effect in the expected language only if it was their native/preferred language. The fact that it was possible to suppress automatic word reading processes in the L1 but not in L2 seems to indicate that suppression efficiency of word reading processes is dependent on the level of language proficiency, and, thus, may be related to resource drains in the system.

The present study aimed to investigate possible language proficiency effects in suppression further to see if similar effects could be obtained using Gernsbacher’s methodology. The study explored the nature and functioning of the suppression mechanism and its place in cognitive architecture through comparing native (L1) and fluent non-native language (L2) suppression efficiency. It is possible that suppression, like other processes, is dependent for resources on some central capacity pool and, thus, its efficiency may be compromised by processing/storage drains elsewhere in the system. Processing drains in the L2 may occur due to extra demands on L2 word decoding and/or meaning retrieval for example (e.g. Favreau & Segalowitz, 1983). Inefficient suppression may thereby be a consequence of inefficient word decoding/meaning retrieval, which in turn may be due to lack of high quality lexical representations as the Lexical Quality Hypothesis suggests (Perfetti & Hart, 2001). There may be complex links between different aspects of the reading process such that small deficits in lower-level processing may become amplified through their consequences for higher-level processes such as sentence or discourse comprehension.

**Experiment**

In order to explore these ideas, a computer-based response-time (RT) experiment was carried out following the methodology of Gernsbacher and Faust’s (1991) homonym experiment but making L1-L2 comparisons. The experiment aimed to study the time-course of interference from contextually inappropriate meanings of homonyms and suppression of these inappropriate meanings in native vs. non-native language.

**Method**

Subjects saw a sentence on computer screen with the final word missing. After reading the sentence in their own time, they pressed a key to get the sentence-final word. In the
critical condition the sentence-final word was a homonym (1),
in the control condition the final word was a non-homonym
of similar length and plausibility (2):

(1) The rain stopped them from playing tennis on the court
(2) The rain stopped them from playing tennis on the grass

Reading time for the sentence-final word was controlled. When
the sentence disappeared, a target word appeared. Subjects’
task was to judge whether the target was related to
the sentence meaning. The target (‘JUDGE’ in this example)
was related to the contextually inappropriate meaning of
the sentence-final homonym in the critical condition (1) and,
thus, the same target was unrelated to both the sentence and
the sentence-final neutral word in the control condition (2).
Differences in judgement time for the target following a
homonym vs. neutral control, both requiring a ‘no’ response,
were taken to reflect semantic interference from the irrelevant
meaning of the homonym.

Design, subjects and materials

The experiment had a 2x4x2 mixed factorial design, the
between-subject variables being group type (native and non-
native), and critical word processing time (SOA 200, 450,
800 or 1000ms), the within-subject variable was relatedness
(Related and Unrelated). Subjects were native English
speakers (native group) and Estonian fluent L2 English
speakers (non-native group). All subjects were university
students and volunteered to participate for a £2 honorarium.
All in all there were 128 subjects in 8 groups (4 native and 4
non-native) with 15-17 subjects in each group.

Forty critical items were constructed, 20 in the Related
(experimental) and 20 in the Unrelated (control) condition.
The former consisted of sentences biased towards the
secondary meaning of an ambiguous sentence-final word with
a target word related to the primary meaning.1 Unrelated
trials differed from Related in that the sentence-final
ambiguous word was replaced by a non-ambiguous word of
similar length that was equally plausible in the context.

Items were divided into groups A (items 1-10) and B (items
11-20), and two presentation lists were formed rotating the
item groups around conditions. 30 fillers were also
constructed, 25 of them were items where the test word was
related to the general meaning of the sentence but unrelated
to the final word, thus requiring a ‘yes’-response, while 5 were
items where the sentence and the test word were clearly not
related. Items were presented in a pseudo-random order -
three different random orders of items were generated,
checked for neighbouring effects and modified if necessary to
avoid any influence of adjacent items.

Results

Figure 1 plots the results of the experiment. The y-axis
presents reaction time differences between the Related and
Unrelated condition in milliseconds at different critical word-
target SOAs on the x-axis. The figure shows that at 200ms
critical word-target SOA both the natives and non-natives
show slower response times in the experimental condition
(related) with respect to the control condition (Unrelated).
This indicates interference from the irrelevant meaning of
homonyms, and is in line with the multiple access view of
word recognition (e.g. Swinney, 1979). Student’s t-test shows
that response times for the Related condition are significantly
slower (p<0.01) from the Unrelated in the non-native group,
and marginally slower (p=0.05) in the natives. At SOA 450
the natives do not experience interference, which indicates
that they have suppressed irrelevant meanings of homonyms,
while the non-native group still experiences significant
interference (p<0.01). The non-natives show successful
suppression of irrelevant meanings at SOA 800. Surprisingly,
the native group behaves differently at SOA 800 experiencing
marginally significant interference again (p<0.1). At SOA
1000 the interference effect seems to return in the non-native
group as well (p<0.05), whereas the effect becomes more
robust in the native group (p<0.01). The return of interference
could be explained in terms of meta-linguistic processing
having an effect at longer SOAs.

Figure 1: Interference and suppression in L1 vs. L2.

\[ \text{RT difference R-UR (ms)} \]

<table>
<thead>
<tr>
<th>SOA</th>
<th>Estonian</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>199.3</td>
<td>94.0</td>
</tr>
<tr>
<td>450</td>
<td>144.2</td>
<td>-3.9</td>
</tr>
<tr>
<td>800</td>
<td>-17.4</td>
<td>113.1</td>
</tr>
<tr>
<td>1000</td>
<td>89.8</td>
<td>76.5</td>
</tr>
</tbody>
</table>

\[ \text{Critical word-target SOA} \]

1 The primary and secondary meanings were decided from the
viewpoint of the L2 speaker, not the native speaker.
The results suggest that the time course of suppression may be different in L1 and L2 reading. Independent samples t-test on the priming effects shows that at SOA 450 and 800 the difference between interference experienced by natives and non-natives is statistically significant at p<0.01 and p<0.05, respectively. At SOA 200 the difference is marginal (p<0.1). The time course of initial meaning activation seems similar though as the non-native group showed statistically significant interference from irrelevant meanings at a very short SOA of 200ms just like the natives did. Also, independent samples t-test shows that at SOA 200, 450 and 800, where there are statistical differences in the amount of interference experienced by the native and non-native groups, there are no statistical differences in average RTs for the Unrelated condition. In fact, at SOA 450 and 800ms the mean RTs for the Unrelated condition are virtually the same in both groups (984 vs. 999ms at SOA 450 and 1052 vs. 1064ms at SOA 800 in the non-native and native group, respectively) suggesting that the differences in interference are not just caused by overall slowing in semantic processing for L2 over L1 readers.

The claim of similar general task performance in the native and non-native group is further supported by RT data to ‘Yes’ response fillers (Figure 2). As Figure 2 shows, mean reaction times to ‘Yes’ fillers are very similar in the native and non-native group at SOAs 200, 450 and 800ms. Thus, the differences in interference between the native and non-native group in the experimental condition cannot be just due to slower semantic processing in the non-native group.

![General task performance: ‘Yes’ fillers](image)

**Figure 2: General task performance in L1 vs. L2**

At SOA 1000, however, RTs differ significantly between the native and non-native group both in the control condition and in ‘Yes’ response fillers. This may indicate differences in confidence or meta-linguistic processing between natives and non-natives when there is more time to analyse items.

**Discussion**

Suppression of contextually inappropriate meanings of homonyms seems to be delayed in L2 compared to L1 while meaning activation does not seem to be slowed. Why this delay in suppression may be is not easy to explain. Since the Estonian and English subjects who participated in the experiment were all randomly selected university students and, thus, had similar levels of education, it seems likely that the two groups did not differ in suppression efficiency in their L1. Assuming that, the finding that suppression is delayed in the L2 may suggest that the mechanism responsible for inhibiting irrelevant meanings shares resources with some other processes that are less efficient in the L2.

As there were no general differences between response speed in L1 and L2, it could be the case that L2 meanings are just harder to maintain in working memory. This hypothesis is based on a study by Miyake, Just & Carpenter (1994) who found in the L1 that maintaining word meanings in working memory imposes extra high demands when these meanings are of low frequency. However, if the frequency information and strength of a lexical representation is based on how many times it has been previously encountered, then L2 meanings would, in that sense, be of much lower functional frequency for the reader than L1 meanings, which could cause a potential drain on resources specific to L2.

This suggestion relates to the Lexical Quality Hypothesis proposed by Perfetti and Hart (2001), which emphasizes the importance of knowledge about word forms and meanings – the ‘quality of lexical representations’, as opposed to processing speed. A high quality representation is a fully specified and ‘tightly bonded set of word constituents’, which are its orthographic, phonological, and semantic specifications. Thus, L2 representations may just have lower quality than L1 representations and, hence, be harder i.e. more resource-demanding to maintain in working memory. This L2-specific resource drain could have important consequences only in situations where task demands are especially high e.g. in cases of response competition like in the experimental condition of the experiment.

Gernsbacher’s account does not make it very clear what a ‘less efficient’ suppression mechanism actually means. Does it entail that suppression is slower, shallower or dysfunctional? Although Gernsbacher and colleagues suggest that suppression may be slower in less skilled readers, from their results it remains unclear whether less skilled readers ever suppress irrelevant information: “In our experiments, we waited what seemed like an eternity in mental chronometry – one full second. However even after a second, less skilled comprehenders had still not suppressed the inappropriate or irrelevant information” (Gernsbacher & Faust, 1991). The results of the present study suggest that ‘less efficient’ suppression can indeed mean just slow. Of course, the nature

---

2 In future studies I hope to make direct L1-L2 comparisons within the same individual. It was not possible to do this experiment both in English and Estonian as the Estonian language has rich morphology, which makes lexical ambiguity in sentence context rare.
of suppression inefficiency could be different in L1 and L2 i.e. being non-existent in L1 but slow in L2.

Although the findings reported here are not convincing enough to claim that the suppression mechanism in reading shares resources with other processes, the results suggest at least that there are effects in suppression that have not been addressed or explained comprehensively, and thus further research is needed in this area. The present author aims to further investigate task- and language proficiency effects in suppression via comparing native and non-native performance on a simpler picture-word interference task, and via manipulating task demands directly in native speakers in the hope of establishing a direct link between processing drains and suppression efficiency. The Lexical Quality Hypothesis (Perfetti & Hart, 2001) seems to suggest that manipulations with low frequency words may yield non-native like suppression patterns in native speakers.

Acknowledgments
The author is grateful to her supervisor Dr. John N. Williams for guidance and support. This research was supported by a Gates Cambridge Scholarship to L. Frey.

References