Depth of Processing and the Negative Priming Effect: Age Differences in Inhibitory Functioning

Lucie Bonneville

A Thesis

In

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy at
Concordia University
Montreal, Quebec, Canada

May 2002

0-612-73344-0

ABSTRACT

Depth of Processing and the Negative Priming Effect:
Age Differences in Inhibitory Functioning

Lucie Bonneville, Ph.D.
Concordia University, 2002

The hypothesis that older adults have more difficulty than younger adults suppressing irrelevant information has been both supported and refuted by past research. The 'gold standard' for measuring inhibitory functioning is the negative priming paradigm. This study examined variables that might help explicate the contradictory findings from past research with this paradigm with the goal of understanding better the age changes in attentional processes. In Experiment 1, 31 young and 31 older adults were tested under three negative priming procedures, considered to require different depths of processing. Older adults did not show inhibition in the low processing procedure but did in the other two procedures while younger adults showed inhibition in all three tasks. The inhibition effect for older adults exceeded that for the young in the task requiring the deepest level of processing. In Experiment 2, 87 older adults, classified as Low, Mid or High in level of Off-target verbosity, believed to be associated with inhibitory deficits, were tested on the same tasks. As in Experiment 1, older adults did not show an inhibition effect in the low processing procedure but did show an effect in the other two procedures. In addition, the inhibition effect for those in the highest group was greater than for the other groups in the deepest processing task. In Experiment 3, 50 young adults and 49 older adults were administered a new negative priming procedure. Level of processing was manipulated in two ways. One manipulation resulted in equal inhibition effects for both age groups and the other resulted in a greater effect for older adults than for younger adults. The results from these experiments support the notion that depth of processing is related to the extent to which older adults will show an inhibitory effect and that requiring greater depths of processing may result in excess inhibition as opposed to a reduction in inhibition. Discussions include an attempt to integrate both the inhibition and the episodic retrieval models. Recommendations include a need for a reevaluation of the negative priming paradigm and for examining the association between different brain functions and different inhibitory functions.

Acknowledgments

I would like to express my immense gratitude to my supervisor, Dr. Tannis Arbuckle, for her incredible patience, insightful wisdom, unswerving encouragement, and adroit direction. She has been nothing but wonderful and, over and above the call of duty, has gracefully given of herself in the preparation of this thesis. I would like to thank Dr. Michael Conway and Dr. Karen Li, internal committee members, for their insightful observations and suggestions, as well as for their understanding and quick turn around of this thesis. My thanks also go to Steven Lapidus who helped me both professionally and personally, in all aspects of my graduate life at Concordia University. I would also like to acknowledge the financial support awarded me by the Fonds pour la Formation de Coercers et l'Aide `a la Recherche. Special thanks to my parents, Jacques and Cecile Bonneville, to my brothers and sisters, to Dr. Nancy Carpenter, and, especially to my brothers, Ray and Franccis, who both encouraged me through thick and thin.

Table of Contents

List of Figure Captions

List of Tables

Introduction

The ability to attend selectively to relevant stimuli while ignoring or suppressing irrelevant ones is a fundamental cognitive process. Theorists have pointed out that selective attention involves not only the active processing of the to-be-attended-to information but also the active inhibition of the to-be-ignored information. Without inhibitory processes, distracting thoughts may interfere with the primary task. For example, while reading a book you may start thinking about the movie you saw last night and end up having to reread the last two paragraphs because you were distracted. Such failures to inhibit irrelevant thought can occur at any age but, in a provocative paper, Hasher and Zacks (1988) hypothesized that inhibitory processes might be particularly vulnerable to the effects of aging. A particular research design, known as the negative priming paradigm, became the "gold standard" to test this hypothesis. The results of about ten years of studies, however, have been inconclusive. The present thesis was initiated in an attempt to understand why the negative priming paradigm gave contradictory results, and thereby to explicate more clearly the nature of the age associated changes in attention and memory that underlay the contradictory findings.

One of the main objectives of the present thesis was to address issues related to methodology. The current negative priming literature, as relates to attentional processes in aging, suffers from great methodological confusion. Using different methods, researchers obtain differing results and in turn come up with different conclusions. An attempt was made here to explore some of these issues by the testing limits of the negative priming paradigm to see when older individuals will show a negative priming effect and when they will not show this effect. Tied to the issue of method, a second goal in the present thesis was to force processing at different levels in order to see how this manipulation may affect outcome on a normal aging population as compared to younger adults, as well as within a sample of older individuals who were, based on speech samples, varied in their ability to inhibit irrelevant information. Another goal of this study was to examine the relationship between interference and inhibitory functioning. Again, different methods of obtaining measures of interference and inhibition have yielded disparate results. The relationship between interference and inhibition is believed to be a negative one because interference should increase with a decrease in inhibitory functioning. The final goal of this study was to examine the relationship of inhibitory functioning, as measured by the negative priming paradigm, with other indices of inhibitory deficits, specifically, those related to the frontal lobe.

The following review will cover the pertinent literature with respect to negative priming and age-related inhibitory decline. Because of the vast confusion in this area which seems directly related to method, it was felt that it is important to review studies in this field from a primarily methodological perspective. When possible, studies are reviewed in chronological order so that the reader may understand more fully what has lead up to the current confusion and why the experiments in this thesis were carried out.

Inhibition

Age-related declines in working memory and attentional processes have been explained using different approaches which include some type of limited capacity model and a cognitive slowing. The fundamental assumption made by a capacity model perspective is that the declines associated with age are dependent on the resources available to an individual and the demands made by the task. When task demands are negligible, for example in automatic perceptual processing, age-related declines should also be negligible because only a small amount of resources are needed. However, when task demands are high, for example in tasks requiring substantial semantic analyses, age-related declines should also be considerable because the demands of the task may require more resources than are available(e.g., Craik & Byrd, 1982; Craik & Rabinowitz, 1984; Hasher & Zacks, 1984). In contrast to capacity models is the notion that age-related declines in cognitive abilities are due to a reduced speed of processing (e.g., Salthouse, 1982). That is, the loss in capacity is the reason for age-related declines but rather the consequence of an age-related slowing in the speed at which information is processed. Hasher and Zacks (1988) hypothesized that it may be inhibitory processes that are particularly vulnerable to the effects of aging and that these processes may be behind age-related cognitive declines.

Hasher and Zacks (1988) proposed that age-related variations in the performance of working memory could be the result of a decline in inhibitory functioning. A faulty inhibitory mechanism would increase the amount of irrelevant information allowed to occupy working memory. Because working memory has limited capacity, this increase would cause a decrease in the space available for task-relevant information. Hasher and Zacks further suggested that, in combination with decreased inhibitory ability, there was also an age-related increase in vulnerability to distraction from unrelated information. Thus, older adults would not only have more difficulty with keeping irrelevant information from entering into working memory in the first place but would also have more difficulty with suppressing it once it was there. Hypotheses based on these kinds of declines have been posed by those working in areas related to working memory such as verbosity (Arbuckle & Gold, 1993), and reading comprehension (Connelly, Hasher & Zacks, 1991).

There is a great deal of evidence that, as one ages, structural transformations take place in the cortex. Relative to other parts of the cortex, the frontal lobes seem to be affected earlier and to succumb to a quicker structural decline (Shilling, Chetwynd & Rabbitt, 2002). The physical changes include reduced blood flow to the anterior cortex (Scheibel & Scheibel, 1975), a reduction in neurotransmitter levels (Arnsten, Cai, Murphy & Goldman-Rakic, 1994) and neuron shrinkage (Haug & Eggers, 1991). Many researchers have posited, and it logically follows, that the cognitive abilities that are associated with the frontal lobes will also be among the first to decline with age (e.g., West, 1996). Among the cognitive abilities that have been linked to frontal lobe functioning is the ability to inhibit irrelevant information (Arbuckle & Gold, 1993; Hartley, 1993; Dempster, 1992; Kramer, Humphrey, Larish, Logan & Strayer, 1994).

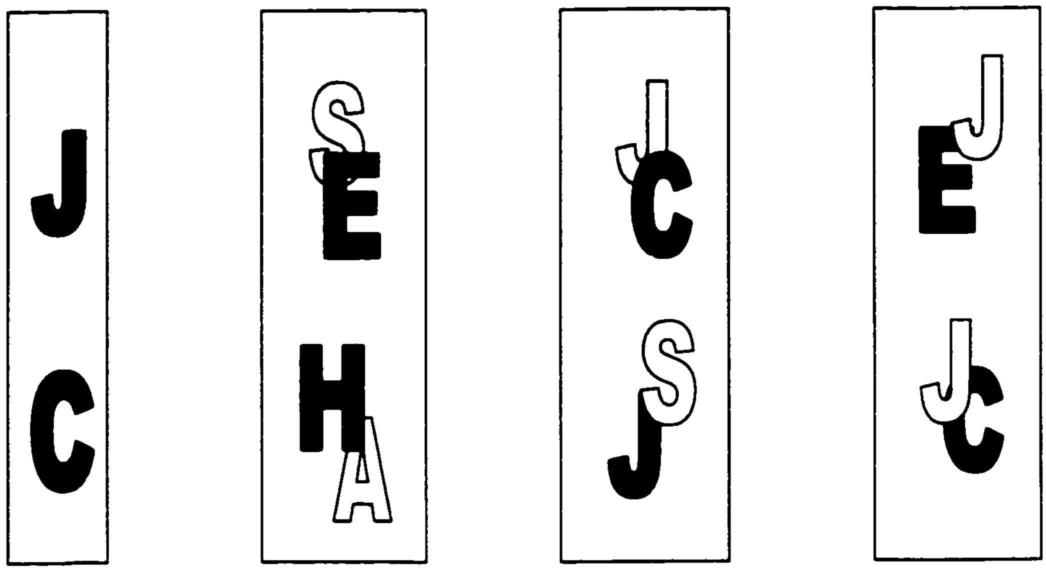
Addressing issues about frontal lobe performance is often accomplished using tasks requiring the suppression of unwanted yet distracting information. For example, one of the more commonly used tests of frontal lobe functioning is the Stroop test (Stroop, 1935). The original Stroop test consists of a list of colored squares and a list of color names (e.g., BLUE) printed in conflicting colors (e.g., the word BLUE printed in green ink). The task requires the suppression of the actual color word when naming the color of the ink. The difference in the time it takes to respond to the color incongruent list and the less taxing colored square list is known as the Stroop Effect. Given the inhibition deficit hypothesis posed by Hasher and Zacks (1988) and the Stroop's association with the structural decline of the frontal lobes, one would expect that older adults would have more difficulty than younger adults on tasks such as the Stroop test. Indeed, with few exceptions and using different variations on the task, an age effect is quite reliable (West. 1996; Shilling, et al. 2002).

One newer experimental paradigm which has gained a great deal of attention with respect to its potential in uncovering the nature of inhibitory functioning is the negative priming paradigm. Based on the notion of a dual processing model of selective attention (Keele & Neill. 1978: Tipper. 1985), and in particular on the work of Dalrymple-Alford and Budayr (1966). Greenwald (1972). and Neill (1977). the negative priming paradigm is believed by some to illustrate the function of inhibition in selective attention. According to Tipper and Cranston (1985), the effect produced by negative priming is a measure of the extent of active inhibition of a behavioral response to distracting information. This paradigm is similar to the Stroop test in that one must also inhibit distracting information in order to respond to the target. However. there is a fundamental methodological difference between these two paradigms. In the Stroop test inhibition is measured by the difference in total reading time for colors versus words whereas in the negative priming paradigm inhibition is assessed by priming the participant with a particular stimulus and then immediately testing the effect of that prime on the participant's response to the next stimulus, termed the 'probe'. Researchers often include. within the same study. different combinations of prime-probe conditions to demonstrate negative priming. interference and even facilitation. An example, as depicted in Figure 1. may help to differentiate among these similar yet distinct concepts. Typically, all these tasks require one to select a target stimulus based on some criterion, Letter Negative Priming Task

Single Letter | Control | Negative Priming | Facilitation

Prime

Probe



Effects	Calculation of Effect
Interference	= Control – Single Letter (greater positive values = greater effects)
Negative Priming Effect	= Negative Priming – Control (greater positive values = greater effects)
Facilitation	= Facilitation – Control (greater negative values = greater effects)

Reaction time measures are taken for the time to respond to the probe display only.

Figure 1. An example of conditions used in a letter identity negative priming task (target letter is in red).

for example, the color red. A single red letter is displayed and the time it takes to respond to this letter is recorded. Next, two letters are presented in the same display, one being red and the other green. The red letter is the target while the green letter is potentially causing some distraction. The introduction of a distractor makes selection a little more difficult. How much does the presence of distractor information interfere with target selection? The difference in time between response to a single red letter and response to a red letter in the company of a green distractor is taken as a measure of interference.

A different manipulation is used to assess active inhibition. When the two letters are displayed, one needs to 'inhibit' the green letter in order to 'select' the red one. Now suppose a second set of letters is displayed. If these two letters are unrelated to the previous two letters, then one would not expect any difference with respect to the amount of time it takes to respond to the red target. This is the control condition. If, however, within this second set of letters the red target letter is the same as the preceding green letter, the one that was previously inhibited, then selecting the target should take longer because the system must overcome the previous inhibition in order to now select it. For example, if on the prime display, the green letter "J" is ignored in order to select the red letter "C", and on the probe trial the letter "J" becomes the to-be-selected letter, selection will be slowed because it must first overcome the initially inhibited representation of "J". The difference in the time taken to respond to the previously ignored probe stimulus on the related pair and the time taken to respond to the new probe stimulus on the unrelated (control) pair is known as the negative priming effect (NPE). The larger the positive value of this difference, the larger the NPE.

Finally, in the facilitation procedure the distractor is always the same. In each prime and probe trial the green letter "J" would appear and it would always be the distractor. In contrast to the negative priming condition, this condition tends to increase the ease of selection. That is, the difference between the control condition and this repeated distractor condition creates a measure of facilitation where the control condition takes longer to complete than does the facilitation condition, yielding a negative value.

With respect to the negative priming paradigm, the inhibitory deficit hypothesis, initially proposed by Hasher and Zacks (1988), predicts the following:

1. Older individuals will not produce a NPE or will do so to a lesser extent than younger adults because of the decline in inhibitory ability.
2. The effects of interference will increase with age because of the increase in susceptibility to distraction.
3. Older individuals will not show facilitation effects to the degree younger adults do because the distractor will continue to impede selection despite being repeated.

The above series of conditions, which are obtained through only slight manipulations in the presentation of stimuli, make for a seemingly neat package to test out the inhibitory hypothesis. However, flower stems often have thorns and, unlike the relatively reliable age-related Stroop effect, so does the negative priming paradigm.

<u>Early Studies and Initial Support for the Inhibition Hypothesis</u>

Due to the interest in the hypothesis that age-related declines in cognitive performance may be due to a decrease in inhibitory functioning, several researchers took advantage of the negative priming paradigm to investigate the relationship between negative priming and age (Hasher, Stoltzfus, Zacks &Rypma,1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994). Kane, et al. 1994; McDowd & Oseas-Kreger,1991: Stolzfus, Hasher, Zacks, Ulivi & Goldstein,1993; Tipper, 1991). All of them used variations on the original version of the paradigm and all found age differences in the NPE. In keeping with the predictions laid out by the inhibition deficit hypothesis, older individuals did not exhibit the NPE whereas younger adults did show the effect. Although not without complicating features, these initial results were seen as evidence supporting the inhibition deficit hypothesis.

McDowd and Oseas-Kreger (1991) based their study on the first experiment of Tipper and Cranston (1985). In their study, a series of letter pairs, one superimposed on the other, were presented one at a time. The task was to identify orally the name of the target. These researchers found that older individuals were more affected by interference than were young individuals. The older group also did not produce a NPE while the younger group were slowed by the negative priming condition (in seconds, .06 and .53 respectively). And, older adults showed a trend toward more facilitation than did younger adults although both age groups showed some facilitation. The age by condition interactions found in this study are consistent with an age-related decline in inhibitory functioning. Unfortunately, each of these interaction effects was of a small magnitude. These investigators called for the development of a more powerful experimental manipulation in order to increase the magnitude of the effects produced.

The increase in facilitation that McDowd and Oseas-Kreger (1991) found in older individuals was subsequently replicated by Kane et al. (1994). These facilitation effects were inconsistent with the hypothesis of age-related decline in the ability to inhibit because, as noted above, facilitation should also decrease as a function of a declining ability to inhibit distractors. Based on the work of Tipper, Borque, Anderson and Brehaut (1989), who found the same counter-intuitive result in young children, McDowd & Oseas-Kreger proposed that the increase in facilitation is likely the result of habituation and that this process of habituation remains intact in the elderly. One becomes so accustomed to the distractor that it is no longer distracting because it is anticipated. Whatever the reason, the finding of greater facilitation effects is important because it suggests that older individuals are processing the distractors at some level. If the distractors are processed, then the question arises, why are the distractors not also being inhibited? One possibility is that the mechanism responsible for interference is different from the mechanism responsible for inhibition.

Using a different type of stimuli, Tipper (1991) also found age differences in the NPE. The stimuli were simple line drawings of objects. The objects were presented in pairs and the target object was always the one which appeared in the centre at the point of fixation. The to-be-ignored object was presented at one of the two sides of the centre target object. Besides the negative priming and control conditions, there was one that consisted of the presentation of an object drawn to have similar features as the line drawing but the lines did not make a unified object. These quasi objects made up the to-be-ignored distractors only in the probe display. It was reasoned that the quasi objects could not be encoded at the level of identification and so this condition could be compared to the control condition to yield a measure of interference.

Tipper (1991) found negative priming for the young adults but not for older adults (15ms and -26ms respectively). In fact, as can be seen by the large negative value, positive priming was elicited for older adults. Interpretation of the positive priming was complicated by the fact that the older adults made significantly more errors in the negative priming condition which suggested that they were more concerned with speed than accuracy. Older adults were also more slowed by interference than were the younger adults. Although complicated by the speed-accuracy tradeoff, these results were in the expected direction with regards to an age-related decline in inhibitory functioning. However, why older adults showed positive priming, as would be associated with a facilitation manipulation, is not at all clear. Perhaps by centering the target in every display the distractor became less of a distraction to the point of habituation for the old. Perhaps the young would have produced an even greater NPE had there been an overlap in the pictures.

One of the difficulties related to the findings from early studies is that of the magnitude of effect that younger adults display. Because the effect sizes, although consistent, are quite small, Kane et al. (1994) attempted to create a more sensitive measure of negative priming. They conducted two experiments with the two-fold objective of creating a more sensitive measure of negative priming and investigating whether or not older adults identify the distractor on some level. Although the target and distractor stimuli were still color coded, the actual stimuli were three-letter nouns (e.g., CAT). Kane et al. found that the young adults produced a substantially larger NPE than had been exhibited in past age-related studies (18ms). Older adults, however, continued to not show this effect (-3ms)[1].

The primary evidence found using the negative priming paradigm acted to confirm the hypothesis of age-related declines in inhibition. Up to this point in time the

---

[1] Several years later, Earles et al. (1997) found a NPE in the old, although less so than in the young, using similar word stimuli.

results were in keeping with those found using the Stroop test, with the NPE being consistently found in younger adults but not in older adults.

General Slowing and Age Differences in the NPE

The work of Hasher and colleagues (Hasher et al., 1991; Stolzfus, et al. 1993) went beyond the sheer demonstration of age differences in size of the NPE to examine the hypothesis that older adults, rather than being unable to inhibit, simply needed more time than young ones to build up the inhibitory mechanism. Based on the well established fact that older adults are generally slower than younger adults on a variety of tasks (see for example, Cerella, 1985; Salthouse, 1982), Hasher et al. (1991) reasoned that perhaps, for older individuals, the increase in time may allow for a slowed and/or inefficient inhibitory function to establish itself and thus show a noticeable NPE. The rationale for assuming that the length of the interstimulus interval (ISI) might be a factor in the size of the NPE came from a study with young adults by Neill and Westberry (1987). These researchers found that when they increased the time between the prime display and the probe display with younger adults, negative priming using Stroop material was reduced.

In their first experiment, Hasher et al. (1991) asked participants to identify a target letter based on color with an ISI of 500ms, which had been the ISI most commonly used. Negative priming was produced in younger adults (8.9ms) but not in older adults (2.4ms). This lack of NPE in older adults was in keeping with the Tipper (1991) and the McDowd & Oseas-Kreger (1991) studies.

In their second experiment, Hasher et al. (1991) examined whether or not older participants needed more time for their inhibitory processes to work. In this experiment the ISI was increased to 1200ms. The same pattern of results was found in Experiment 2 as had been seen in Experiment 1. Younger adults continued to show a NPE (7.5ms) and older adults again did not show the effect (-1.8ms). Thus, giving increased time did not produce an inhibitory effect in the older adults. In addition, the effect found in the young did not depreciate substantially from Experiment 1 to Experiment 2 as would have been predicted by Neill and Westberry.

Stolzfus, et al. (1993) used the same version of the negative priming paradigm that Hasher et al. (1991) had used except that the ISI was now increased to 1700ms. The increase in ISI was another attempt to allow enough time for inhibition to build up in older individuals. These researchers again found an effect for young adults (10ms) and no effect for older adults (1ms).

Because there continued to be a lack of negative priming in older individuals with increases in prime-probe interval, Stolzfus et al. (1993) took a different approach in their second experiment. They were motivated to discover if indeed there was active inhibition of the distractors. They decreased the prime-probe interval from 1700ms to 300ms. The logic behind this decrease was that perhaps the inhibitory processes of older individuals occur rapidly and also dissipate rapidly. If this were the case, then longer intervals would result in a lack of negative priming because the effect had 'been and gone' whereas at very short intervals it would be more noticeable. Again, only the young were affected by negative priming (8ms for the young group versus 0ms for the older group).

These two studies by Hasher and colleagues are interesting in a few ways. The fact that older adults did not produce a NPE under conditions of long ISIs refutes the idea that the lack of NPE seen in the earlier studies is due solely to a general slowing of the aging cognitive system. Also refuted was the idea that an inefficient system may act and let go of inhibited material too quickly. Time per se may not be an environmental factor associated with this effect for older people.

Age-Related Negative Priming Studies Based on Location of the Target

The initial evidence from studies using the negative priming paradigm supported the notion of some form of age-related decline in inhibitory function. Because it seemed worthwhile to pursue this line of research, two studies addressed the issue of whether the decline in inhibitory function is global, dispersing throughout the various cognitive systems or, discrete, contained only within certain systems and only under certain conditions (Connelly & Hasher, 1993; McDowd & Filion, 1995)? Based on the idea that there are at least two visual pathways conveying information to the anterior cortex (Ungerleider & Mishkin, 1982), one sending incoming data to an identity processor and one to a location processor (Desimone, Albright, Gross, & Bruce, 1984), Connelly and Hasher reasoned that there may also be at least two inhibitory systems. Evidence in support of this notion comes from work by Tipper, et al. (1989). They found that location suppression is present in young children in second grade who do not show identity suppression. In keeping with the 'first in last out' idea, these findings suggest that location suppression may stay intact in older adults while identity suppression may be declining because they are dependent on different inhibitory systems.

Based on the method used by Tipper and McLaren (1990), Connelly and Hasher (1993) asked participants to respond to the location of a target by pressing one of four keys on the keyboard, each key representing a particular target location. The target was always the same, an "O", and the single distractor was also always the same, a "+". Using a negative priming paradigm, an inhibition of return (IOR) condition was also included among the conditions (see Figure 2). In the IOR condition, the target in the probe occupied the same position as the target in a target-only prime. The inhibition of return effect, thought to be an important component in spatial selectivity, is believed to slow responses to targets on probe displays when the target in the preceding prime is in the same location (Posner & Cohen, 1984). It was postulated that the NPE for location may tap a similar mechanism as that of the inhibition of return effect and so both effects may cause older adults to look toward novel sites.

Connelly and Hasher (1993) found negative priming for location in both young (28ms) and older adults (28ms). They also found facilitation instead of a slowed response in their inhibition of return condition for both younger (-7.5ms) and older participants (-31.1ms). Connelly and Hasher note that both the materials and the mode of response were different in this study as compared to previous studies of identity negative priming. As well, the fixation cross in their first experiment was very similar to the distractor.

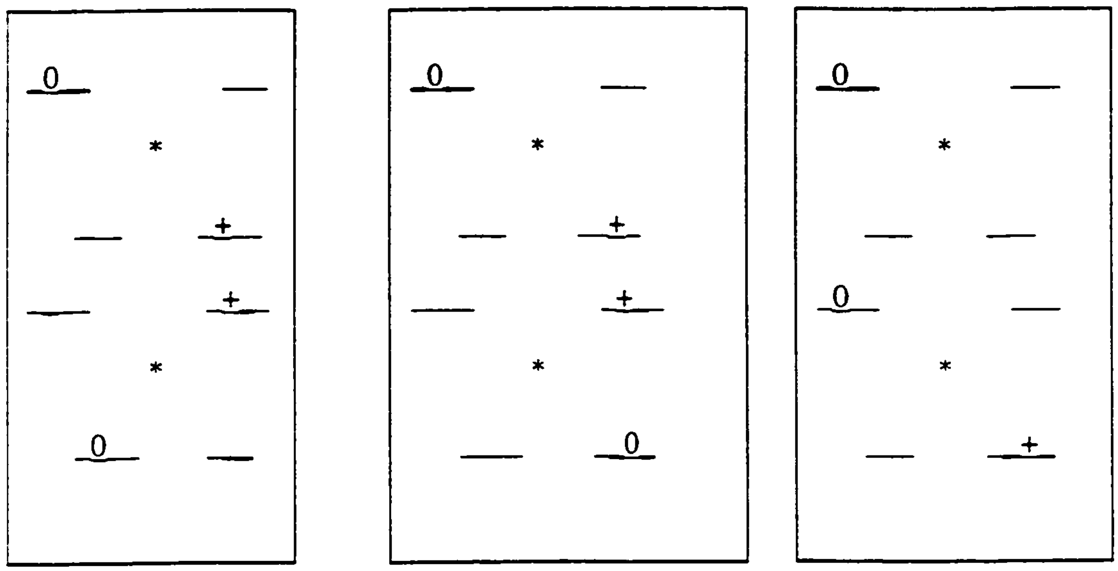
In a second experiment, Connelly and Hasher (1993) changed the fixation mark to an "=" sign and presented it in green. In addition, following Tipper, Weaver, Cameron, Brehaut, & Bastedo, (1991) who used vocal responses in a location negative priming task, they changed the mode of response to calling aloud one of four numbers (1 to 4) which corresponded to the location of the target. Again, no age differences were found in negative priming, with young slowing by 12ms and older adults slowing by 9ms. Although the effect sizes for both age groups were smaller than with the manual response used in the first experiment, older people still produced a NPE for location. Smaller effects were also found by Tipper et al. (1991). Worthy of notice is the change in the effect size and the changes made to the display. It may be that the fixation mark in the

Location Negative Priming Task

Control | Negative Priming | Inhibition of Return (IOR)

Prime

Probe



Effects | Calculation of Effect

Negative Priming Effect = Negative Priming – Control (greater positive values = greater effects)

Inhibition of Return (IOR) =IOR – Control (greater negative values = greater effects)

Reaction time measures are taken for the time to respond to the probe display only.

Figure 2. An Example of Conditions Used in a Location Negative Priming Task (Target Letter = '0'; Foil = +; Fixation point = *).

first experiment, which was very similar to the distractor, actually resulted in an increased level of competition within the display. To the perceptual and inhibitory systems, it may have seemed as if there were two distractors to ignore versus one.

Because of the possibility of there being two separate inhibitory mechanisms, one related to identity which may be impaired in older adults, and one related to location, perhaps not being impaired with age, a third experiment was performed by Connelly and Hasher (1993). In addition to the location conditions, they included an identity component asking participants to call aloud a target letter, indicated by color, which had been placed in one of the four possible positions. Older adults produced a NPE for location (27.5ms) and an identity/IOR effect (31.3ms) but not an effect for identity alone (-2.8ms). Younger adults exhibited all three effects (22.1ms, 32.1ms and 7.6ms, respectively). These researchers argue that despite the fact that the mode of response differed across their experiments, (manual spatial mapping, vocal spatial mapping, and vocal identity) a NPE in a negative priming location task was elicited in older adults. Based on their findings, they suggested that the mechanism responsible for inhibiting location is saved in old age whereas the mechanism responsible for inhibiting identity is affected by the aging process.

Filion, McDowd and Baylis (poster presentation cited in McDowd & Filion, 1995) used a comparable location task to that of Connelly and Hasher but found a reduced NPE for location in older adults relative to younger adults. Noting that Connelly and Hasher (1993) had used self-paced whereas they used forced pacing, Filion et al. retested a group of older adults and found that when self-pacing was employed, the same older adults produced the same magnitude of effect that had been found in the younger sample. As a result of these discrepancies, McDowd and Filion (1995) conducted a methodical investigation of the effects of pacing on the negative priming of location.

McDowd and Filion (1995) ran two different sequences in their first experiment: a self-paced task and a forced-paced task. Negative priming was produced in both age groups but only for the self-paced version of the task. Negative priming for location was only found in the younger group in the forced-paced task. As well, a significant negative correlation between negative priming and the amount of time participants waited to initiate the trial set was found for older adults (-.46). So, the longer older adults waited to initiate the trials, the smaller the NPE. These researchers concluded that the inhibitory function involved in location is not necessarily spared with age, as has been previously suggested by Connelly and Hasher (1993).

The conclusion to be drawn from the research to this point is that, older adults do not show inhibition of distractor information in identity based tasks, but do show it, for the most part, in self-paced location tasks. One interpretation is that there are at least two inhibitory mechanisms. The inhibitory mechanism responsible for the location-based NPE is relatively insensitive to aging but, unlike the identity based NPE, is sensitive to time manipulations. Looking back at the identity based studies reviewed so far, there have been a mix of forced (McDowd & Oseas-Kreger, 1991; Tipper, 1991; Stolzfus, et al., 1993) and self paced (Hasher et al., 1991; Connelly & Hasher, 1993; Kane et al., 1994) procedures all of which resulted in age differences in the NPE. The self-paced procedure allows a variation in time between trials while the forced-paced does not allow time variation. As previously noted, the manipulation of ISI does not affect the NPE for identity nor does time between trials. But, time does seem to affect the NPE associated with location such that greater amounts of time prior to trial onset lead to less effect in older individuals. This finding suggests that, for the mechanism responsible for location, inhibition dissipates more quickly for the old than for the young. Location suppression may show less age decline than identity suppression but it does appear to be declining in some way. It may be that it declines slower or starts declining later in adulthood.

After the Honeymoon

All of the studies mentioned so far, using various displays and sequencing, provided compelling evidence of smaller NPEs in older adults relative to younger adults in identity priming tasks. These findings are consistent with the view that older individuals suffer from an impaired inhibitory mechanism as compared to younger individuals, but this interpretation is based on the assumption that the NPE is a measure of inhibition. However, there were two early studies, using different variations of the paradigm that found equal amounts of negative priming in older and younger adults (Sullivan & Faust, 1993; Kramer, et al. 1994). These results spurred a great deal of debate as to exactly why equal NPEs were found.

In the study by Sullivan and Faust (1993), superimposed pictures were presented in pairs. Participants were required to say out loud the name of the target object which was denoted by one of two colors (red or green). These researchers believed that superimposing pictures may lead to a greater NPE. They argue that there may be more competition involved with superimposed pictures versus separated pictures (Tipper, 1991), separate letters (Hasher et al, 1991; Stolzfus et al., 1993), separate words (Kane et al., 1994), and superimposed letters (McDowd & Oseas-Kreger (1991). It was argued that pictures have a semantic quality over and above their identity and so may be encoded in a qualitatively different way than letters. A semantic quality, in combination with a more competitive presentation may lead to a greater effect for young adults and a noticeable effect for older adults.

Sullivan and Faust (1993) employed several conditions using a forced-pace sequence of events. The five prime-probe conditions were as follows: a control condition; a negative priming condition; an attended repetition condition where the target prime and target probe pictures were the same; an attended semantic condition, where the target prime and target probe pictures were different but were semantically related (e.g., cat-dog); and, finally, a negative priming semantic condition where the to-be-ignored prime picture and the target probe picture were different but were semantically related.

Sullivan and Faust (1993) found some interesting results. Negative priming based on identity was found for both older adults (27ms) and for younger adults (15ms). Negative priming based on semantic relatedness was not produced in either age group. The same pattern of results was found for a second older group as compared to the first older group (identity NPE, 21ms).

The 15ms effect for younger adults found in Sullivan and Faust (1993) is the same size as that obtained by Tipper (1991) who also used pictures. Older adults however, not only produced a larger NPE than they had in past studies but also, although not significantly different, their mean NPE exceeded that of the younger adults by 12ms. All other variables (fixation time, exposure time, prime-probe interval, inter-trial interval) were the same as those used in past studies.

The second study required participants to identify a target from yet another type of array (Kramer et al. 1994). Participants identified a target letter by pressing the corresponding key on a keyboard. The target was indicated by an underline and was presented in an array of four letters. The three distractor letters were all of the same identity. Kramer et al. did not find age differences in the NPE nor in the amount of interference exhibited.

Besides using a keyboard to identify targets versus naming the letter vocally, there seem to be two major differences between the method used by Kramer et al. (1994) and the methods used by those who found an age difference. First, there was more than one distractor present in the prime and probe displays. It may be that, similar to the Sullivan and Faust (1993) study, the presence of three identical distractors caused more competition than the presence of only one distractor despite the fact that they were not superimposed. Another difference is that an underline was used to denote the target versus being indicated by color or position. Other variables are all within the limits set by past studies.

The results of both the Kramer et al. (1994) and the Sullivan and Faust (1993) studies call into question the nature of the apparent age-related decline in inhibitory function for the identity of incoming information. Any or all of the methodological differences between these two studies and those finding an age difference in the size of the NPE could be relevant to the different outcomes. Under some circumstances inhibitory functioning of older adults does not appear to be efficient. Under other circumstances, perhaps related to more pressure being put on the system via increased competition, it appears to function as well as in younger individuals.

One of the possible interpretations of this puzzle is that the more difficult the task or, the more processing required of the task, then the more likely one is to find an effect for older individuals (e.g., Kieley & Hartley, 1997; Kane, May, Hasher, Rahhal & Stoltzfus, 1997). For example, initial studies involved overlapping letters printed in different colors (McDowd & Oseas-Kreger, 1991; Hasher, et al., 1991; Tipper, 1991), separate words in different colors (Kane, et al., 1994), and separate pictures to be chosen on the basis of location (Tipper, 1991). These task displays require only a rather superficial perceptual analysis. Tasks involving an underlined target surrounded by three distractors (Kramer et al, 1994) and overlapping line drawings (Sullivan & Faust, 1993) all produced the NPE in both younger and older adults. Kramer et al. (1994) note that their task was more difficult than those used in previous studies which found no effect for older adults. Identity per se is likely not the sole determinant of the effect, or lack thereof, seen in older adults. It is reasonable to assume that when a semantic load is put onto the system it would react differently than when identity is based on a more perceptual attribute such as color. It may be that if inhibition is the cause of the NPE, the incoming information has to go through several 'inhibitory hoops' depending on the amount or type of processing required of the system and these hoops may be differentially affected by age.

Alternative Explanations of Negative Priming

The Episodic Retrieval Explanation of Negative Priming

A comparison of tasks that do or do not show the NPE in the elderly suggests that the former tend to require considerable perceptual or semantic processing of the actual stimuli whereas the latter tend to be tasks where minimal processing of the stimuli is required and a simple decision rule suffices (e.g., select red, ignore green). May, Kane, & Hasher (1995) suggested that, although the negative priming condition produces slower responding relative to the unrelated control condition in both types of tasks, the mechanism responsible for the slowing in tasks requiring deeper decision-type processing may be an episodic retrieval process. The episodic retrieval theory, proposed by Neill and Valdes (1992) and Neill, Valdes, Terry and Gorfein (1992), and based on the work of Logan (1988), offers a different explanation for the NPE. This theory proposes that when a stimulus is presented, the retrieval of the most recent episode of that stimulus is automatically induced. Each stimulus carries with it information gained from prior exposure including its qualities and any response pertaining to it. So, for example, if the word 'dog' was presented in the prime display as a distractor, it would be given a 'no respond' tag. If on the probe display 'dog' now becomes the target, the previous 'no respond' tag is automatically retrieved, causing a discord between this tag and the present need to 'respond'. Thus, the increased time it takes to overcome the conflict causes negative priming to occur.

The episodic retrieval explanation is different from that of the explanation based on inhibition. In the former, the assumption is that the retrieval of the most recent tag given to a current stimulus (respond or no respond) takes place during the presentation of that stimulus. For the purposes of negative priming, the slowdown is caused by and occurs at the probe display. This explanation is in contrast to the assumption made by the inhibition account, that the slow down occurring during the probe display is a result of the amount of inhibition that took place during the prime display. How well the distracting stimuli in the prime are inhibited will dictate whether a response is slowed in the probe.

This alternative account of the NPE confuses matters with respect to potential age-related deficits in inhibitory functioning. May et al. (1995) argue that inhibition functions to deprive further analysis of a recently ignored stimulus in contrast to facilitating actual selection. In this case, provided a 'to-be-ignored' stimulus can be identified at a superficial level of analysis, active inhibition can prevent further analysis of the to-be-ignored stimulus after a selection has been made on the prime trial. On these types of tasks, the impaired inhibitory processes of older adults results in a failure to inhibit after selection on the prime trial and hence no slowing on the NP probe trial. However, if the to-be-ignored stimulus must be processed to a deeper level before it can be identified as 'to-be-ignored, then the inhibitory process has already been by-passed. In this case, argue May et al. (1995), both stimuli are fully processed on the prime but are automatically tagged with the outcome of the decision, "ignored" or "selected". Because this tagging process is automatic, on the NP probe trial both young and old are slowed in their selection of the previously ignored stimulus because they have first to remove the "ignore" tag in order to select the item. In an attempt to clarify this matter, May et al., (1995) argue that the studies that have produced age equivalent negative priming have been unknowingly stimulating a mechanism responsible for episodic retrieval rather than an inhibitory mechanism. They suggest that there are at least three experimental contexts in which negative priming is induced by episodic retrieval. The first is one where the target identification is difficult at the level of the probe. They argue that if the probe target is difficult to identify, the older adult will rely upon the previous episode for help in identifying it. The second context is one where a large proportion of all the experimental trials have a repeated target and/or a repeated distractor. Repetition means that the condition for the current response is the same as that for the previous response. Extensive repetition should facilitate episodic retrieval, improving performance and inducing a response set that will carry over to the negative priming conditions. The third context is a task which involves a yes/no response or a lexical decision versus naming alone. This kind of task is more likely to induce postlexical processing and, when postlexical processing is induced in the context of negative priming, then the information from a previous trial would be called upon to aid the current response.

Temporal Discrimination Explanation for Negative Priming

Milliken, Joordens. Merikle, & Seiffert (1998) have proposed that negative priming is not due to inhibition but rather to a kind of 'temporal discrimination'. They have shown that an increase in reaction time will take place even when selective attention is not required during the prime. In their study they presented only one white-colored word as the prime, telling participants to ignore it, and then presented two words, with the original white-colored word now color-coded red as target, on the probe. Responses were slowed in this condition in comparison to the control condition where prime word and probe target were unrelated. They argue that because there is no selection during the prime, there can be no inhibition taking place. They propose that, when the target on the probe is to be selected, it is first scrutinized as to whether it can be automatically retrieved, which will happen if it has been recently encountered, or whether it needs to be evaluated further because it is new. Because the prime is to-be-ignored in both their new method (single word) and in the usual negative priming set up (distractor), it was never fully processed and hence the system is not quite sure what to make of it on the probe. This lack of clarity as to its temporal location (recent versus new) creates some confusion and therefore slows responding more than if it had been recent (automatically retrieved) or new (quickly processed).

Although the temporal explanation for negative priming is not without merit, it does not consider fully the cognitive actions that may take place when participants are 'ignoring' the prime. Tipper (2001) points out that the system is not passively ignoring the stimulus but rather is processing it on some level, because otherwise there would not be an increase in reaction time on the probe. Tipper argues that the results of Milliken et al. (1998) are in keeping with the current view that any input which does not match the selection criteria will be inhibited. In the case of the Milliken et al. example above, the white colored word does not match the target criterion "red", and hence is inhibited. Tipper further argues that one cannot ignore the entire 'selection' process when trying to appreciate the complexities of the NPE.

Studies Comparing Episodic Retrieval versus Inhibition

Kane et al. (1997) explored the potential dual mechanisms responsible for the NPE. As well, they looked at whether predictions based on an episodic retrieval account of negative priming would be borne out given specific manipulations. In essence they asked whether these mechanisms (inhibitory and episodic retrieval) rely on the contextual details of the experiment. In their first experiment, using five letter nouns as stimuli, they manipulated the difficulty of probe target identification. To do this, they either degraded the target at the probe level (difficult) or left it intact (not difficult). They hypothesized that, for the difficult condition, the experience of the previous distractor on the prime would be used to aid in reducing the current difficulty in identifying the target, thus producing a NPE due to episodic retrieval. Alternatively, the non-degraded condition was believed to produce a NPE due to inhibition as the previous episode would likely not be called upon for target identification. In addition to the conditions mentioned above, these researchers included a degraded prime distractor condition and a degraded prime target condition.

Kane et al. (1997) found that under the normal display condition the young showed a small NPE of 7ms and the old showed no NPE (1ms). Both the old and the young showed a NPE under the degraded probe target condition (28ms and 22ms respectively). The degraded prime distractor condition yielded no effect for the young and facilitation for the old (+17ms). These results were consistent with an episodic retrieval explanation. Further support for this explanation is the fact that there was no correlation found between the NPE under normal conditions and the NPE under the degraded condition. This latter finding suggests that perhaps two separate and independent mechanisms are at work. Further evidence was gained through a second experiment, with only older adults participating.

In their second experiment, Kane et al. (1997) manipulated the time that the prime and probe displays were presented. The displays were set at either 300ms (standard time) or for 150ms (brief time). Three conditions were set up. In the first, the prime was displayed for the standard time with the probe being displayed for the brief time. In the second, both prime and probe were displayed for the brief time. Finally, in the third, the prime was brief and the probe was standard. The idea was that if the probe time was brief and the prime was a standard length of time, then episodic retrieval would aid in identifying the probe target. On the other hand, response to a standard probe after a brief prime should not be induced through episodic retrieval. They found that the brief probe time preceded by the standard prime did indeed yield the largest NPE (23ms) whereas the standard probe preceded by the brief prime yielded the least (1ms). The brief prime and probe resulted in an 8ms NPE. Although they concluded that both degraded and brief probe displays induce episodic retrieval in older individuals, the problem remains as to whether it is the difficulty of the task which is eliciting the NPE or episodic retrieval per se.

Kieley and Hartley (1997) argued that when a reliable NPE is found in older individuals, the stimuli, particularly the distractor, are processed to a greater extent than when older individuals do not show a NPE. Because the Stroop test yields a large effect, and older individuals are consistently more affected by the test than are the young, they reasoned that the use of Stroop materials in a negative priming paradigm would ensure a significant amount of processing of the stimuli and therefore lead to at least as much NPE as would be seen in the young. In their first experiment they found an equal NPE for both young (90ms) and old (91ms). These researchers argue that perhaps the inhibitory mechanism in older individuals is not impaired but only utilized when the task becomes difficult. Alternatively, based on May et al.'s (1995) argument, they suggest that perhaps episodic retrieval was induced because they had a high proportion of repeated-target trials. In their second experiment they eliminated repeated target trials and hypothesized that this change would reduce or eliminate the induction of episodic retrieval. However, again they found no significant age difference in NPE between old (43ms) and young (35ms) although the magnitude of the effect was less than half that of the previous experiment.

Schooler, Neumann, Caplan and Roberts (1997) called into question the hypothesis that older individuals have reduced inhibitory capacity. They disagree with May et al.'s (1995) claim that the results found by Kramer et al. (1994) were due to a location effect versus an identity effect. In their first experiment they removed possible spatial confounds by using overlapping stimuli that were centrally positioned. Based on Logan's (1990) assertion that an automatic episodic retrieval is unlikely to occur for a picture to word transition, they tried to discourage episodic retrieval by using overlapping pictures in the prime display and overlapping words in the probe. The idea was that the pictures would not be present and therefore would not be cues for automatic retrieval at the level of probe. Five conditions were used as follows: control, repeated target, semantically related prime and probe target, semantically related prime distractor and probe target (semantic negative prime), and conceptually identical prime distractor and probe target (conceptual negative priming, e.g., picture of dog and the word DOG). Positive priming occurred in both the repeated target condition and in the semantically related prime and probe target condition. A NPE was found for both old and young under both the conceptually and semantically related negative primes.

It is important to note, that although Schooler et al. (1997) found no interaction between age and condition, the NPE for the older group was actually slightly larger than that for the young in both the semantic (55ms vs 27ms) and conceptual (69ms vs 21ms) conditions. This tendency was also seen in studies by Sullivan and Faust (1993), Kramer et al. (1994) and Kane et al. (1997).

In Schooler et al.'s (1997) second experiment they removed the two positive priming conditions in order to rule out the possibility that these conditions may induce episodic retrieval. The same pattern of results was produced, although the NPE for the old was slightly smaller than in the first experiment. In the semantically related condition the old showed a 24ms NPE and the young showed a 13ms NPE. In the conceptually related condition the old showed a 27ms NPE while the young showed a 26ms NPE. The fact that they found a NPE in older adults, even after discouraging episodic retrieval, led Schooler et al. to argue that there may be an intact inhibitory mechanism in older individuals.

If one compares the magnitude of the NPE in Schooler et al.'s two experiments, it appears that the removal of episodic retrieval inducement did in fact reduce the NPE found in the old but did not seem to affect that of the young. It is unfortunate that these researchers did not directly compare the two groups of older individuals to test if the reduction in size of the NPE was significant. Nor did they provide the standard deviations for their NPEs, making it impossible for the reader to calculate this statistic. Even though they were not significantly different from the young, the two older groups may have been different from each other. This comparison would have allowed for a better assessment of the effect that the discouragement of episodic retrieval may have had on the older groups.

Following Kiely and Hartley's (1997) argument that task difficulty and increased processing of the stimuli is the 'environmental condition' needed to induce NP in the elderly, Gamboz, Russo and Fox (2000) manipulated the difficulty of response to overlapping letter stimuli using a paradigm similar to McDowd and Oseas-Kreger (1991). It was their assumption that older individuals would not show a NPE in the 'easy' condition. The easy condition had overlapping letters with the target letter presented in either dark red with a dark green distractor or vice versa. In the difficult condition the target was in dark red with a light red distractor (or dark green/light green). It was believed that the similarity in color would make the task more difficult than when presented in two different colors. No interactions were found although there were main effects of age, difficulty and condition. The young had a 8.5ms NPE in the easy condition and a 8.9ms NPE in the difficult condition while older people showed a 7.1ms and 14.9ms NPE respectively. Interestingly, the old did show a NPE in the easy condition which is contrary to what would be expected given both past findings (McDowd & Oseas-Kreger, 1991) and the difficulty hypothesis.

In Gamboz et al.'s (2000) second experiment, the 'difficult' and 'easy' conditions were presented in separate blocks. It was reasoned that perhaps, in the first experiment, the old used the same strategy with both conditions because the conditions had been intermixed within the same block. The same results were found except that in addition, a condition by difficulty interaction was seen with the NPE being greater in the difficult condition. Again the young showed a NPE of 9.5 in the easy condition and 14.5 in the difficult condition while the old showed a 6.3ms and 17ms NPE, respectively. The magnitude of the effects suggest that the mechanism responsible for the NPE, at least in this study, relies on selection difficulty overall but statistically the old are not reacting less (or more) than the young.

In a third experiment Gamboz et al. (2000) tried to deal with one potential reason that a NPE was found in the easy condition contrary to the results of McDowd and Oseas-Kreger (1991). They created a non-overlapping letter condition in order to have a task that was even easier than the original 'easy' condition. The NPE from the non-overlapping condition was then compared to that of the 'easy' condition from

Experiments 1 and 2. A condition by difficulty interaction was found. In the non-overlapping condition, a 7.9ms NPE was found and, for the more taxing form, it was 11.4ms.

Pesta and Sanders (2000) also manipulated task difficulty, or levels of processing, by having participants complete a negative priming task under semantic prime and nonsemantic prime conditions. In the semantic condition, the prime selection rule was to name the heavier of two objects (e.g., van and nest), both presented in white on a dark background. In the nonsemantic condition, the prime selection rule was to name the word with more letters from a pair of words, also presented in white on a dark background. In both conditions, the probe selection rule was based on color, (e.g., name the green word while ignoring the red word). Because the prime selection rules required making a comparative judgment, either based on meaning or on word length, the participants had to attend to and process both the target and the distractor. Older adults produced a NPE in both the semantic (20ms) and in the nonsemantic (33ms) conditions, whereas the young produced a NPE in the semantic condition (26ms) but not in the nonsemantic one (0 ms). Statistical analysis showed that the old had a significantly larger NPE than the young in the nonsemantic condition. This finding is unusual given the tendency for younger adults, at least statistically, to show as much or more NPE than older adults. The study had two unusual features, either or both of which could account for the unusual result. The use of a comparative judgment task likely increased the amount of processing that was done on the prime distractor, and may have contributed to increasing the NPE. Alternatively, the switch in selection criterion between prime and probe trials could have negated to some degree the prime-probe conflict that is inherent to negative priming trials. This negation of effect, if it occurred, would likely be greater for the nonsemantic condition because the switch is a within-domain switch, from one nonsemantic feature (number of letters) to another (color of word). It would also probably be greater for those who have more efficient attentional control processes, who, in this instance, are likely to be the young adults. It is worth noting that the switching of the selection rule between prime and probe trials alters the prime-probe relationship so much that the results of Pesta et al. may, in fact, be irrelevant to the understanding of the NPE.

To sum up this section, in most of the later negative priming studies, older adults do show a NPE. Furthermore, the criteria proposed by May et al. (1995), under which one would predict either an NPE or no NPE for older adults depending on the elicitation of episodic retrieval versus an inhibitory mechanism, do not seem to be valid or at least are insufficient to explain the findings.

The Levels of Processing: The Forgotten Variable

A variable which could help explain the discrepant findings of past research is levels of processing. Levels of processing, also known as 'depth of processing', has been defined as the depth at which stimuli are processed, where 'shallow' processing implies the analysis of physical or sensory features and, greater 'depth' refers to a greater amount of semantic, abstract or cognitive analysis (Craik and Lockhart, 1972). The idea is that the 'episodic memory trace' is automatic and the trace increases in resilience as depth of processing increases (Craik & Tulving, 1975).

From an episodic retrieval perspective, it may be that, with low trace resilience (shallow processing), young adults maintain a hold on the weak perceptual trace of the prime distractor and it's corresponding 'ignore' tag. Because there is a weak trace of the prime distractor, its 'ignore' tag resurfaces to create a short conflict before its identity can be responded to on the probe, and therefore, the young show a small NPE. Because of an already compromised memory, older adults may not maintain a hold on a weak, low resilient trace. If there is no trace of the preceding prime 'ignore' tag for the old, then a conflict does not take place at the level of the probe, and therefore, older adults do not show a NPE under these conditions. At deeper levels of processing, the trace of the prime distractor's tag is more resilient. Perhaps, because of this resilience, older individuals do hold onto the tag and, a conflict takes place at the level of the probe in both age groups. Thus, at deeper levels of processing, the young and the old show a NPE because they both must contend with the trace of the previous tag. This hypothesis suggests that episodic retrieval has the potential to take place in all cases of negative priming and, retrieval, will take place depending on the age of the individual and, the level at which the stimuli have been processed.

As has been previously noted, although not significantly different, there is a tendency for older adults to show larger NPEs than that shown by the young, when the type of stimuli calls for greater depth of processing (Schooler et al., 1997; Sullivan & Faust, 1993; Kramer et al., 1994; and, Kane et al., 1997). It may be that, when processing is very deep, the resiliency of the tag causes a greater degree of conflict than it does at a shallower processing depth. This greater conflict may be more difficulty for older individuals to contend with than it does for the young. If this is the case, then older adults will show a greater NPE than do the young, as depth of processing increases.

From an inhibitory deficit perspective, depth of processing may dictate the degree to which a distractor is inhibited and, in turn, how difficult it is to retrieve, after inhibition has taken place. A defective inhibitory mechanism may not 'kick in' when a stimulus is processed at a very shallow level and, therefore causes no difficulty when the distractor is retrieved. However, once in motion, a defective inhibitory mechanism may work too well, causing greater difficulty in the retrieval of a previously inhibited stimulus than had the stimulus been processed to a lesser extent. It may be that when inhibition is strong, it takes longer for both age groups to retrieve an inhibited stimulus but, because older individuals have a compromised inhibitory mechanism, they have even more difficulty than the young do. Thus, when processing is very deep, older individuals should show a larger NPE than that shown by the young.

Interference and the Negative Priming Effect

One assumption that is related to the inhibition deficit hypothesis is that there is a negative relationship between inhibition and interference. Tipper, Weaver, Cameron, Brehaut and Bastedo (1991) suggested that there are two mechanisms at work during selection: excitation and inhibition. Excitation acts to intensify relevant information while inhibition acts to decrease availability of irrelevant information. Whereas several researchers have found a negative relationship between interference and inhibition (e.g., Tipper, Bourque, Anderson & Brehaut, 1989), others have not found this relationship (e.g., Driver & Tipper, 1989; Beech & Claridge, 1987). A negative relationship, intuitively, is expected between inhibition and interference because, if one is highly affected by interference, then it is likely that one has a reduced capacity to inhibit irrelevant stimuli. There have been several studies on aging using the negative priming paradigm that included measures of interference in order to investigate this possible relationship.

Stolzfus, et al. (1993) found that both the young and the old showed similar effects of interference but only the young showed a NPE. A non-significant correlation between interference and negative priming was seen in the young and in the old as well as in the two age groups combined. In their Experiment 3, where only young adults participated, they added two additional measures of interference; the Stroop task and a reading task. The reading task consisted of reading two passages aloud. One had distracting material implanted within the target text and the other had only target text. They found that, among the interference measures, only the letter naming interference task and the Stroop task were significantly correlated with one another. None of the interference measures were related to the observed NPEs. Connelly and Hasher (1993) found similar results in their location study. Interference was produced in both age groups but it did not correlate with the NPE.

Unlike Stolzfus et al. (1993), Kane et al. (1994) did find a small, but significant correlation between interference and negative priming, but, only for the older group (-.36). This association was in the direction that would be predicted, given an inhibitory deficit. Having also found a facilitation effect in older adults, Kane et al., like McDowd and Oseas-Kreger (1991), came to the conclusion that older individuals do perceive the distractor on some level. The process associated with target selecting can be slowed by interference or facilitated by the surrounding distractor information but remains unaffected by negative priming. In their Experiment 2, as in the first experiment, they found a significant negative correlation between interference and negative priming (-.50).

The Kane et al. (1994) study, which found correlations between interference and negative priming, differed from the Stolzfus et al. (1993) study in terms of the stimuli used and the size of the NPE elicited. It may be that the three letter nouns used by Kane et al., which produced a larger NPE in the young, also produced a greater range of NPEs in the older sample, increasing the power to detect a relation between interference and the NPE. However, the picture becomes more complicated by the fact that positive correlations have been found by some researchers (Sullivan & Faust, 1993; Kieley & Hartley, 1997)

Sullivan and Faust (1993), using superimposed pictures that had yielded a rather large NPE in the old, also included two prime conditions that were used to get at two different types of interference effects. Recall that semantically related and semantically unrelated primes had been used in their negative priming conditions. The difference between the prime reaction times on the semantic condition and those on the unrelated condition was used to measure semantic interference. The other, more commonly used measure of interference was the difference between the reaction times to unrelated primes and those to a single picture prime condition. A significant positive correlation was found between semantic interference and negative priming but the correlation between the more common measure of interference and negative priming, although non-significant, was in the expected negative direction. As in the Kane et al. (1994) study, stimuli that require greater processing also appear to allow for relationships between interference and the NPE to emerge. It is unclear, however, why the semantically related interference measure in Sullivan and Faust's (1993) study would correlate with negative priming in a positive direction. A positive correlation between the Stroop effect and NPE, which was based on Stroop material, was also found by Kieley and Hartley (1997).

Are There More Than Two Inhibitory Mechanisms?

As noted above, we know that the distractor is processed on some level because we see effects of both facilitation and interference in older adults. However, in some cases no NPE is shown whereas in other cases older adults do show the NPE. The debate in the literature has focused primarily on two arguments. The first is the argument that, because equal NPEs have been found in the young and the old, this finding constitutes the evidence needed to refute the inhibitory deficit hypothesis. The second argument is that an episodic retrieval mechanism, not the deficient inhibitory mechanism, is in use in those cases where equal NPEs have been found.

Posner and colleagues (Posner & Peterson, 1990; Posner, 1992) suggest that there are two attentional systems and that each serves different functions. The posterior system is believed to adjust our orientations to stimuli based on physical attributes such as location, color and shape. The anterior system, on the other hand, is based primarily in the frontal lobes and deals with decision-making functions and the processing of semantic information. Posner and Peterson further note that these systems, while maintaining separation, are interconnected and state that there is "a possible hierarchy of attention systems in which the anterior system can pass control to the posterior system when it is not occupied with processing other material" (Posner & Peterson, 1990, p. 35). If this is indeed the case, then the door is open for many possible combinations of effects, given the tapping of specific or multiple brain systems. The need arises to investigate these possible interconnections. One way to address some of these potential links is to include neuropsychological measures of frontal lobe functioning in studies using the various negative priming paradigms. For example, the Stroop test is often referred to as a measure of interference but is also considered a measure of efficiency of concentration (Lezak, 1995) and, therefore, a measure of inhibitory control with the ability to detect frontal deficits (Shilling et al., 2002). The positive correlation between the Stroop test and the NPE based on Stroop material (Kieley & Hartley, 1997) is not surprising if the two are seen as tapping the same or similar mechanisms in the frontal lobe. Stolzfus et al. (1993) found that two of their interference measures (the Stroop and letter interference) related to one another but not to the NPE which was based on letter identification. This inconsistency is symptomatic of the difficulties in identifying the neuropsychological correlates of the NPE, and fuels speculation that different negative priming paradigms may be measuring different abilities. To date there have been relatively few studies of negative priming that included measures of possible neuropsychological correlates.

Earles et al. (1997) administered several cognitive measures to a large adult sample ranging from 20 to 90 years of age. Their measures included negative priming, the Stroop, reading distraction, free recall, perceptual speed and working memory. The negative priming was based on similar words to those used by Kane et al. (1994). All age groups produced a significant NPE, although it was significantly smaller in the oldest group then in the youngest group. As well, all age groups were equally affected by interference. Small but significant negative relationships were found between negative priming and age and negative priming and interference and a small positive relationship was found between negative priming and speed. Perceptual speed, used as an index of processing efficiency, was found to mediate the covariance associated with age and negative priming and, with age and interference. Interference, but not negative priming, was found to mediate the covariance between working memory and age. These findings are provocative because they suggest that interference rather than inhibition is related to age associated decline in working memory and that inhibition and interference, is associated with processing efficiency.

Kramer et al. (1994), along with their negative priming conditions (as described above), administered a series of tests believed to be related to inhibitory processing. These tests included two tests that are considered measures of frontal lobe processes, the Wisconsin Card Sorting Test, the Stopping task (Logan & Cowan, 1984), as well as a memory self report measure, the Cognitive Failures Questionnaire (CFQ). Only the CFQ was related to negative priming, with more self-reported cognitive failures associated with smaller NPEs. The CFQ ..as also negatively related to the frontal lobe measures but not to the NPE. It seems that the self reports on the CFQ, which asks questions pertaining to a range of everyday practical situations, is related to several possible inhibitory domains but these domains are not necessarily related to one another.

Summary and the Present Study

The first studies that used the NPE as an index of inhibitory dysfunction in older adults gave credence to the general inhibition deficit hypothesis posed by Hasher and Zack (1988). Later studies, however, called this hypothesis into question. The size of the identity-based NPE in older adults has varied from nonexistent to substantial depending on the stimuli and the experimental condition. In many of the later studies older people showed a NPE that was at least equal to that of younger adults. The reasons for these variations in size of the identity-based NPE in older adults are not completely clear, but larger NPEs do seem to be associated with increased difficulty and deeper processing of the target and distractor.

General age-related slowing does not seem to be related to the production of the NPE in older adults, although perceptual speed, may mediate the relationship between age and the NPE shown for selection based on color. The mechanism, or mechanisms, related to location-based negative priming do seem to be intact in older individuals although some variations of the paradigm suggest that it may also show some decline. The notion that different brain systems are responsible for different outcomes may help explain these disparate findings. Studies that did not find a NPE in older adults, for the most part, have been those which used stimuli based on location, color, and lower levels of processing demands. The demands made by these experiments may have been those which made use of the more posterior systems. The studies that found equal effects for young and old are those whose demands may be tapping anterior, frontal lobe functions. Other studies have found larger effects for older individuals as compared to younger adults but these differences have not been significant.

Further evidence in support of the use of different brain systems for different stimuli and task demands comes from correlational data. Negative correlations between the NPE and interference, when present, seem to be associated with tasks that require relatively low levels of stimulus analysis. Positive correlations between them, when found, seem to be associated with tasks that require more or deeper analysis of the stimuli. These differences could be due to the use of different types of mechanisms such as those associated with inhibitory functioning versus those responsible for episodic retrieval. However, equal NPEs have been found for the old and the young even under conditions which, according to May et al.'s (1995) criteria, episodic retrieval should not have occurred (e.g. Schooler et al., 1997). In general, predictions based on the May et al.

(1995) criteria have not been very successful in discriminating the manipulations that produce no NPE in the old from those that produce an equal effect in the old and young. Teasing apart the possible effects of episodic retrieval versus those related to inhibition is not as straight forward as was first assumed. Indeed, at this point in time and, based on past studies, it may be best to understand negative priming from both perspectives as opposed to one over the other.

Verhaeghen and de Meersman (1998) conducted a meta-analysis in an attempt to establish whether or not older adults, overall, show less of a NPE than the young. They found that, for identity-based tasks, older adults did show less of an effect, whereas for location tasks they showed equal effects to the young. However, there is a potential problem with their analysis with respect to the current review. Several of the more recent studies were not included in their analysis and in these studies age equivalences were found.

So far, with few exceptions, the results of these negative priming studies have been assessed in a kind of vacuum. Only a few studies have looked at relationships between the NPEs and other measures of attentional control, apart from interference. There is some evidence that susceptibility to interference coming into working memory may be related to an altogether different mechanism than the one, or more, involved in inhibition or episodic retrieval. For example, processing efficiency has been found to be related to the association between age and the NPE, while interference has been found to be associated with the relationship between age and working memory. The Stroop test, believed to be related to frontal functioning, appears to be positively related to negative priming when the task demands are those likely related to frontal functioning and unrelated to negative priming when task demands suggest the use of Posner's hypothesized posterior system. More information is still needed to understand the NPE. With all the differences in results, examination of the relationship between negative priming and various neuropsychological measures would provide additional information. Relating the NPE to other more established measures, in addition to interference effects, and using various types of stimuli that require different levels of processing, may help us better understand what is going on.

The present study was designed to address some of the possible reasons why older adults do and do not show the NPE and how these reasons may relate to inhibitory declines in older adults. The issues under study include the effects associated with levels of processing, the association between the NPE and interference and the NPE with other frontal measures using identity-based procedures. Because pacing (self versus forced) seems to affect location-based tasks and does not seem to be an issue for identity-based tasks, both location and pacing will not be addressed here. Location, when relevant, is counterbalanced and a forced-paced procedure is used in all tasks.

Experiment 1

The main issue addressed in Experiment 1 is that of task differences in the effect seen in older adults. This issue was explored by comparing within-subject changes in the magnitude of the NPE across three different tasks that required different levels of perceptual and semantic analysis. A task first used by MacDonald, Joordens and Seergobin, (1999) was chosen as the task requiring the greatest processing of the three due to the requirement of comparing the meaning of the target and distractor. It was hypothesized that, whereas young adults would show negative priming in all three tasks, the NPE for older adults would vary depending on the amount of stimulus processing demanded by the task, and might even exceed that of the young in the deepest processing task. The second of the three tasks was designed to require processing of both the target and distractor but would not require semantic processing. Rather, it was designed to require the processing of the stimuli at the perceptual level only. The third task was the Letter task used by several researchers in the past. This latter task was believed to require the least amount of processing.

Method

Negative Priming Tasks

Identification of Letters Task (Letter Task). As in the studies by McDowd and Oseas-Kreger (1991) and Gamboz et al. (2000), the stimuli consisted of the letters: A, C, E, H, J, and S. The participant was presented with a single letter or a pair of letters and asked to call aloud the target letter and to do so as quickly but also as accurately as possible. In pair presentations, the distractor letter was superimposed on the target letter with the location of the superimposed letter changing randomly (see Table 1). One letter was in green, the other in red. Letters were in a font size of 48, and, hue, saturation and brightness were selected in order to maximize visual similarity on those dimensions (Green: hue; 22790; saturation; 62548, Brightness; 65535, Red: saturation; 65535, brightness; 65535). Half the participants in each age group were assigned to name the red letters as targets and half the green letters, with assignment to color condition being alternated based on order of appearance at the laboratory. Three conditions were used: A Single Letter Condition where one letter was presented and was in the target color; a Control Condition where the target and distractor on one trial were unrelated to the target

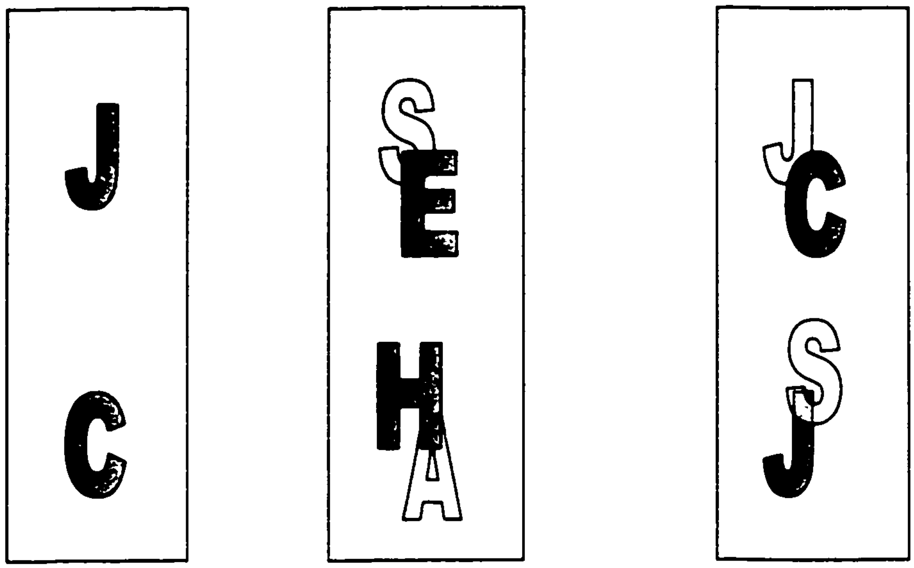
Table 1. Examples of Stimuli and Conditions Used in the Three Negative Priming Tasks.

Letter Task

Single Letter | Control | Negative Priming

Prime

Probe



Diamond Task

Control | Negative Priming

Prime

Probe

Time Task

	Control		Negative Priming	
Prime	Minute	Hour	Month	Day
Probe	Year	Day	Hour	Day

and distractor on the next trial, and a Negative Priming Condition where the target in every pair after the first in each block was the same letter as the distractor in the immediately preceding pair. Thus, for both the control and negative priming conditions, the probe on one trial also acted as the prime on the next trial. There were 66 presentations per condition (3 blocks of 22 letter pairs in each condition). Conditions were varied between blocks. The blocks were randomized so that subjects were presented with a single block of one of the three conditions which was followed by a second condition and then the third. The next three blocks were presented in the same manner as was the final three blocks. Each of the three sets of three blocks could be in any order as long as the three conditions were each presented within a set. An example of one possible presentation of the letter task is as follows: Single – Control – Negative Prime; Control – Single – Negative Prime: Negative Prime – Single – Control. The difference between the reaction time for the Single Letter condition and that for the Control condition constituted the measure of interference. The difference between reaction time for the Control condition and that for the Negative Priming condition constituted the measure of the NPE.

<u>Comparative Judgment of Diamonds Task (Diamond Task)</u>. Stimuli consisted of diamond shapes (see Table 1), created using the Wingding font in six different sizes (9, 12, 14, 18, 24, and 48 points). Diamonds were printed in black on a white background. The participant was presented with two diamonds of different sizes and asked to call aloud the position (right or left) of the larger diamond. Participants were asked to respond as quickly but also as accurately as possible. The two diamonds were placed at five spaces to the left and right of the center respectively. A trial consisted of a prime pair

followed by a probe pair. There were a total of 20 trials per condition (4 blocks of 10 prime-probe trials each). Blocks were randomized such that each participant in each age group received a different one of the 16 possible combinations. There were two conditions embedded within each block: In the Control condition the target diamond on the probe was different in size from both the target and distractor on both the preceding prime pair and the prime pair on the next trial. In the Negative Priming condition these same constraints applied except that the target diamond in the probe pair was always the same size as the distractor diamond in the preceding prime pair. The position of the target diamond on the probe trial was counter-balanced so that on one-half of the control trials and on one-half of the negative priming trials the target was in the same position as the target on the preceding prime trial. On the other half of both conditions the target was in the opposite position of the target on the preceding prime target. As well, there were an equal number of targets presented on the right of the screen as there were on the left.

<u>Comparative Judgment of Time Durations Task (Time Task)</u>. (MacDonald, Joordens and Seergobin, 1999). Eight time stimuli, second, minute, hour, day, week, month, year, and decade, were presented two words at a time in a predetermined sequence (see Table 1). Participants were asked to call aloud the word that corresponded to the longer time period (e.g., if presented with the words 'year' and 'minute', the participant was to respond with 'year') and to do so as quickly and as accurately as possible. The word on the left of each pair ended five spaces from the centre and the word to the right started five spaces from the centre. Words were presented in black on a white background and were typed using a font size of 48. There were a total of 22 trials per condition (4 blocks of 11 prime-probe trials each). Randomization and counter-

balancing of blocks, conditions within blocks, and position of stimuli within pairs was done in the same way as described above for the Diamond task.

All tasks were programmed on a Macintosh LC630 computer using Psyscope 1.0. (Cohen, MacWhinney, Flatt & Provost, 1993). Stimuli were presented on an Apple Multiscan 20 Display monitor. Voice activation and measurement of reaction time in milliseconds was performed by the Psyscope Button Box using a clip-on Sony high impedance ECM-909A microphone.

Participants

Initially, only the Time and Letter tasks were used. Sixteen older (aged between 66 - 83 years, M = 74.75, SD = 5.09 with a mean education level of 15.31 years, SD =1.66) and 16 younger (aged between 18 - 27 years, M = 22.75, SD = 2.54 with a mean education of 15.44 years, SD = 1.50) adults were tested on these two tasks. The Diamond task was added in an attempt to tap the "mid- point" of task processing demands. An additional 15 older (aged between 65 - 81 years, M = 72.47, SD = 5.73 with a mean education level of 14.93, SD =3.77) and 15 younger (aged between 19 - 28 years, M = 24.20, SD = 3.10 with a mean education level of 16.07, SD =1.83) adults completed the three tasks. Thus, a total of 31 participants in each age group completed the Time and Letter tasks and 15 out of those 31 from each age group completed all three tasks. Independent samples t-tests were performed on age and education within each group to establish that there were no differences between the first 16 and the second 15 subjects. None of the t-tests were significant, (t-values with degrees of freedom=29, ranging from .37 to -1.43, ns).

The final sample consisted of 31 older adults (aged between 65 - 83 years, M = 73.65, SD = 5.45) and 31 young adults (aged between 18 - 28 years, M = 23.42, SD = 2.87). Older participants had a mean education of 15.13 years (SD = 2.84, range of 7 to 19). Younger adults had a mean education of 15.74 years (SD = 1.67), range of 13 to 19). All subjects were naïve with respect to the contents of the study. As well, all subjects were screened for color blindness. Older participants were recruited via a participant pool of older community dwelling adults which has been compiled over many years. Young participants were recruited via posters placed at Concordia University and word of mouth. All participants received an honorarium of $8 with older adults receiving an additional $4 to cover travel to the campus.

Procedure

Each participant was tested individually. A consent form was given to the participant to read and to sign. After the participant signed the form demographic information was gathered.

Participants were then seated in front of the computer screen and fitted with the clip-on microphone. The microphone was tested and adjusted to ensure that it would pick up the participant's voice. Participants were told that the tasks required them to respond orally and that they should not try to correct themselves as the computer would pick this up as another response. The three negative priming tasks were then administered. In order to minimize any possible effects of 'warming-up' to the computer or fatigue, the sequence of these tasks was counterbalanced across participants. Participants were given three practice trials for the Letter and the Time tasks but not for the Diamond task because of difficulties in programming. For all tasks, the first trial of each block was not used in calculations. Also, for all tasks, a forced-paced procedure was used. The sequences of events for the three tasks were as follows:

Letter task. A fixation point (+) was presented in the middle of the screen for 500ms. A pair of superimposed letters (or a single letter) was then presented in the centre of the screen for 250ms. A blank screen immediately followed the letter pair and stayed blank until the participant said the target letter aloud. The time in ms from the offset of the letter pair to the verbal response was recorded (reaction time). The tester recorded any errors made by the participant. This series of events continued for the 22 pairs of each block.

Diamond task. The fixation point (+) was presented in the middle of the screen for 500ms followed by presentation of the diamond pair (prime). The pair remained on the screen until the participant responded. The time in ms from the onset of the diamond pair to the response was recorded (prime reaction time). A blank screen immediately followed the response and remained blank for 500ms. The fixation point was then re-presented for 500ms followed by the second diamond pair (probe). The diamond pair remained on the screen until the participant responded. The time (in ms) from the onset of the diamond pair to the response was recorded (probe reaction time). The screen went blank for 500ms following the probe response. The tester recorded any errors made by the participant. This series of events was repeated for 20 presentations within each block.

Time task. The fixation point, stimulus duration and inter-stimulus interval for each trial were identical to those used in the Diamond Task. The series of prime-probe events continued for 22 presentations per block.

At the end of the experiment participants were thanked and paid for their participation. Any questions participants had were answered.

Results

The alpha level for all analyses was set at .05. Trials in which either of two kinds of errors occurred were omitted from analyses of the reaction times (RT), which were the data of primary interest. Participant errors were made when a participant called aloud the wrong target. Equipment errors occurred as a result of the microphone either setting off the voice activation too quickly or not responding quickly enough. Preliminary analyses were conducted on both types of errors, in order to ascertain whether the dropping of trials on which errors occurred would bias the analyses of the RTs.

Error Analyses

As can be seen in Table 2, equipment errors were relatively rare. Expressed as a percentage of total responses, equipment error rates for young adults ranged from 0% in the Diamond control condition to 4.5% in the negative priming Time condition. Equipment error rates for older adults ranged from 0% in both Diamond and two of the three Letter conditions to 1.25% in the negative priming Time condition. Analyses performed on equipment error rates showed no significant age or condition effects, alone or in interaction, in the Letter task or the Diamond task and only an age effect in the Time task, $F(1,60) = 6.74$, $p < .05$, with younger subjects having a mean equipment error of 1.87 ($SD = 2.90$) and older adults having a mean equipment error of 0.52 ($SD=1.06$).

Participant errors were also infrequent. In percentage terms, younger adults' rates ranged from 0% in the Diamond control condition to 2.4% in the Letter interference condition. Participant error rates for older adults ranged from 0.7% in the Letter NP

Table 2. Means and Standard Deviations for Participant and Equipment Errors on the Three Negative Priming Tasks as a Function of Age Group.

Age Group		Condition						
			Letter		Diamond		Time	
		Single	Control	NP	Control	NP	Control	NP
		Equipment Errors						
Young	M	0.06	0.10	0.13	0.00	0.03	1.77	1.97
	SD	0.36	0.40	0.34	0.00	0.18	2.79	3.01
Old	M	0.00	0.06	0.00	0.00	0.00	0.48	0.55
	SD	0.00	0.25	0.00	0.00	0.00	1.03	1.09
		Participant Errors						
Young	M	1.39	1.58	1.13	0.06	0.00	0.94	1.19
	SD	2.58	2.95	1.93	0.36	0.00	1.81	1.70
Old	M	0.77	0.58	0.48	0.03	0.06	1.96	2.09
	SD	1.71	1.31	1.18	0.17	0.24	1.92	1.85

Note. NP = Negative Priming.

condition to 4.8% in the Time NP condition. Analyses performed on participant error rates showed no significant age or condition effects, alone or in interaction, in the Letter task or the Diamond task and only an age effect in the Time task, $F(1,60) = 5.43$, $p < .05$, with younger subjects having a mean error of 1.06 ($SD = 1.75$) and older adults having a mean error of 2.03 ($SD=1.90$). When those committing more than five participant errors on either

the control or the negative priming condition (6 individuals) were removed from the main reaction time analyses described below, there were no differences in the results. The same technique was done removing those participants who had more than five equipment failures (5 individuals), and again, there were no differences in the results. There were no individuals who had a high number of both types of errors. Therefore, all participants were included in all the analyses of RTs.

Reaction Time Analyses

A 2 (age) x 3 (condition) between-within ANOVA was performed on the Letter task data using mean RTs (see Table 3). There were significant main effects of age, with longer RTs for older adults, $F(1, 60) = 16.94$, $p < .001$, and condition, with longer RTs for the negative priming condition than for the control condition, $F(2, 120) = 54.61$, $p < .001$. These were qualified by a significant age by condition interaction, $F(2, 120) = 4.22$, $p < .05$. Post hoc tests for condition effects within age group showed that for young adults, but not for old adults, RTs were significantly longer in the negative priming condition than in the control condition, indicating that only the young adults had a significant NPE. The post hoc tests also showed significant a interference effect of the same magnitude (17ms) for young and older adults.

Table 3. Means and Standard Deviations (MS) for the Three Letter Task Conditions, the Interference Effect and the Negative Priming Effect as a Function of Age Group.

Experiment 1

Group		Pairs			Effects	
		Single Letter	Control	Negative Priming	Interference	NPE
Young						
	M	185.6_a	203.1_b	212.9_c	17	10
	SD	32.5	33.6	35.8		
Old						
	M	231.2_a	248.4_b	247.4_b	17	-1
	SD	44.1	53.2	43.9		

Note. Means with different subscripts within each age group differ significantly at $p < .005$ (t-tests using Bonferroni correction). NPE = Negative Priming Effect.

A 2 (age) x 2 (condition) between-within ANOVA was performed on the mean RTs of the Diamond data (see Table 4). The difference between younger and older adults on overall RTs was not significant, $F(1, 28) = 3.52$, ns. There was a significant main effect of condition, with negative priming trials having longer RTs than control trials, $F(1, 28) = 24.73$, $p < .001$, but no significant age by condition interaction, $F(1,28) = .20$, ns. The NPE was significant for both young (74ms) and older adults (116ms).

A 2 (age) x 2 (condition) between-within ANOVA was performed on the mean RTs of the Time data (see Table 4). There were significant main effects of age, with older participants being slower, $F(1, 60) = 14.36$, $p < .001$, and of condition, with negative priming trials having longer RTs than control trials, $F(1, 60) = 69.66$, $p < .001$. These were qualified by a significant age by condition interaction, $F(1, 60) = 15.71$, $p < .001$. As can be seen in Figure 3, both younger and older adults showed a NPE, but the NPE for the older adults was significantly greater than the NPE for the young adults.

Correlational Analyses

Correlations of the NPEs from the three tasks with the measure of interference from the letter task and age are presented in Table 5. For the two age groups combined, all three NPEs were significantly correlated with interference, but the direction of the correlations was negative for the Letter and Time tasks and positive for the Diamond task. Within the older group, the Letter NPE was significantly related to interference in a negative direction. In the young, all three correlations between the NPEs and interference were significant and negative. The only significant relationship among the NPEs themselves was between the Diamond and the Letter NPEs. For the younger age group this relationship was positive. For the older group this relationship was of the same

Table 4. Means and Standard Deviations (MS) for the Comparative Judgment Time Task and the Comparative Judgment Diamond Task as a Function of Age Group.

Experiment 1

Task and Group		Control Condition	NP Condition	NPE
Diamond				
Young				
	M	627.6	701.6	74
	SD	(135.1)	(155.5)	
Old				
	M	777.9	893.8	116
	SD	(215.0)	(301.4)	
Time				
Young				
	M	954.7	1001.6	47
	SD	(184.1)	(186.4)	
Old				
	M	1120.9	1260.6	140
	SD	(205.6)	(254.2)	

Note. NP = Negative Priming; NPE = Negative Priming Effect

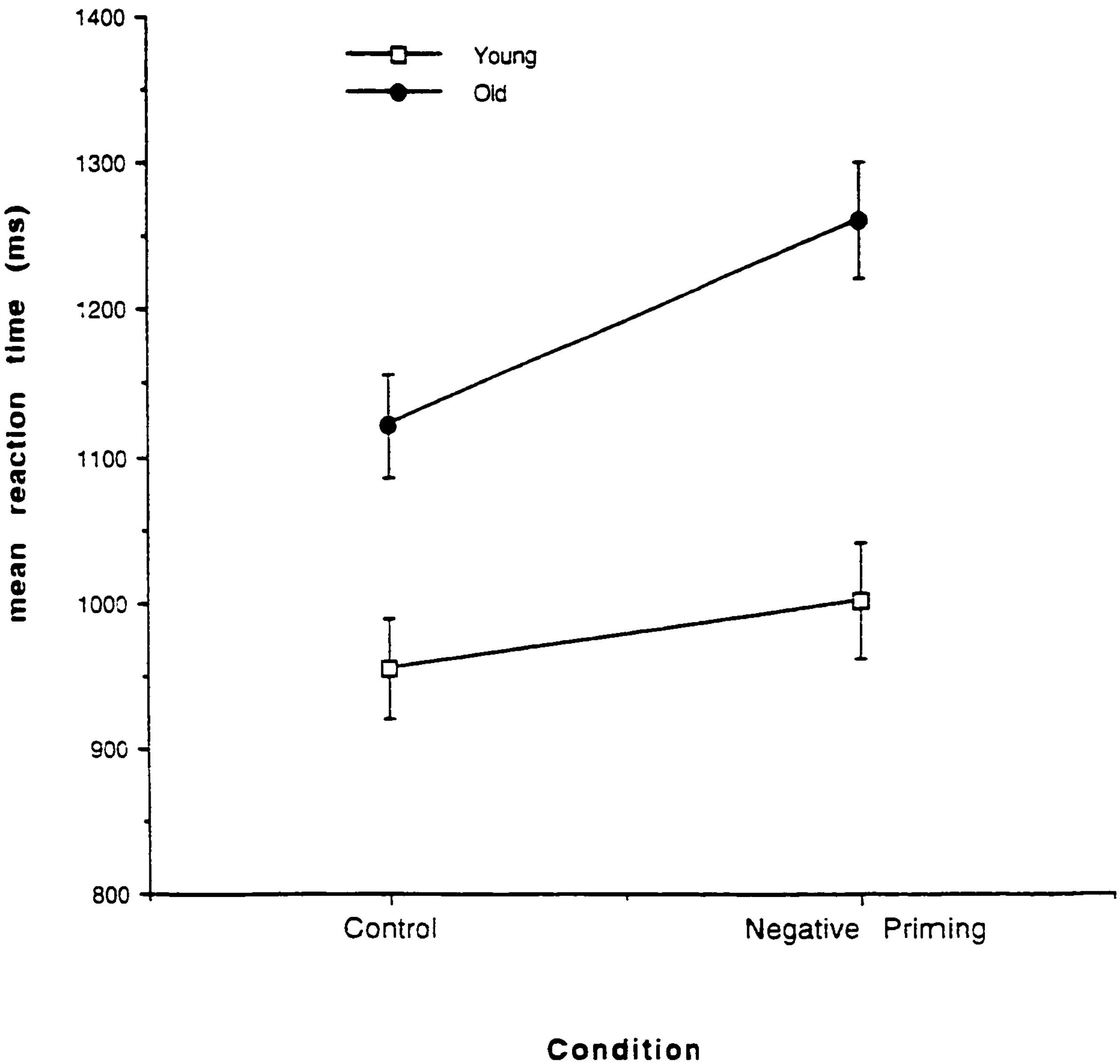


Figure 3. Mean reaction time and standard errors for the Time task as a function of age and condition.

Table 5. Correlations Between All Negative Priming Effects, the Measure of Interference and Age as a Function of Age Group.

	Negative Priming Variables		
Group	Letter NPE	Time NPE	Diamond NPE
Younger Adults			
Time NPE	.00		
Diamond NPE	.53*	-.25	
Interference	-.42*	-.35*	-.55*
Age in Years	.11	.22	-.03
Older Adults			
Time NPE	.21		
Diamond NPE	-.51*	-.02	
Interference	-.54**	-.25	.49
Age in Years	.12	-.25	-.39
Overall			
Time NPE	-.05		
Diamond NPE	-.30	.04	
Interference	-.47**	-.25*	.37*

Note: n per cell was 31 per group and 62 overall for all tasks except those involving the Diamond task with 15 per group and 30 overall.

* $p<.05$; ** $p<.01$

magnitude but in the opposite direction. However, correlations involving the Diamond task should be viewed with some caution, because the n per group was 15 as opposed to 31 for the other measures. Within each age group, age in years was unrelated to all of the effects.

Discussion

Consistent with most past studies (e.g., McDowd and Oseas-Kreger, 1991) but not with the Gamboz et al. (2000) study, younger adults, but not older adults, showed a NPE in the Letter task. Also consistent with past research, older and younger adults showed a statistically equivalent NPE when the task difficulty was increased on the Diamond task by requiring a comparative judgement of the target and distractor. Finally, unlike all but one previous study (Pesta & Sanders, 2000), older adults showed a significantly greater NPE than did younger adults in the Time task, a task which appears to require an even deeper level of processing than either the diamond or letter task.

Why did the older adults have such a large NPE on the Time task? It is difficult to use Pesta and Sanders' findings to help answer this question, because, as already pointed out, their methodology was unusual. Because they used a mixture of the negative priming paradigm and the task switching paradigm, their results may not be representing NPEs. However, it is worth noting that both their priming conditions did require comparative judgments as did the diamond and time tasks used here, and that this enforced processing of both the target and the distractor might be one factor in inducing large NPEs in older adults.

Kiely and Hartley (1997) suggested that perhaps older adults only show an ability to inhibit when pressed to do so, as when task requirements are more difficult. In previous research, a larger NPE found in the young supported the view that older individuals experienced a deficit in inhibitory functioning. The fact that older adults are showing a greater NPE than the young suggests that their inhibitory mechanism may become more efficient when deeper processing is required. Or, extending Kiely and Hartley's argument, it is possible that, when the system is really pressed, as in the Time task, the inhibitory mechanism works too well in older adults, differentially increasing the difficulty of retrieving previously inhibited information.

Another possible reason for the current findings is that maybe a separate and distinct mechanism responsible for episodic retrieval is at work, as suggested by May et al. (1995) and Kane et al. (1997). According to May et al.'s criteria, because the Time task requires a comparative judgment, it should elicit episodic retrieval versus inhibition. The initial judgment, or lexical decision, on the prime is more likely to induce postlexical processing which means that information from a previous trial would be called upon to aid the probe response. This argument was first posed by May et al. in an attempt to explain equal negative priming in the old and the young. However, we now have an instance where the old produce a greater NPE than the young. If a separate mechanism responsible for episodic retrieval is at work, then what would a greater NPE mean? Does this mean that older individuals have a more or a less efficient episodic retrieval mechanism? Does efficiency of the episodic retrieval mechanism mean that the previous 'do not respond' tag causes a greater amount of conflict when the tag must change to 'respond', or, does efficiency mean that the tag will be retrieved but there will be less conflict? If we use the young as our 'efficient comparison group', then it may be that when the mechanism responsible for episodic retrieval declines with age, it causes an increase in the amount of time to retrieve the episode. This increase in time may be the result of a longer conflict occurring before being able to respond.

The lack of directional consistency with respect to the correlations between interference and the different NPEs makes for further difficulty in concluding which mechanism, or combination of mechanisms, are at work under each condition. Kieley and Hartley (1997) assert that a negative relationship between interference and the NPE is consistent with an inhibitory explanation because more susceptibility to interference could be the result of a less efficient inhibitory mechanism. They also assert that a positive relationship is consistent with an episodic retrieval view because the conflict between 'do not respond' and 'respond' will interfere with the current need to respond to a greater extent with greater susceptibility to interference. If this is the case, then it is not at all clear which mechanism is at work for any of the negative priming tasks because there was no clear directional pattern of correlations either within the older age group or across the entire sample

One way to perhaps disentangle this confusion is to administer these same measures to a group of older adults who are believed to have decreased ability to inhibit irrelevant information. If those with inhibitory deficits can be differentiated by one or more of these negative priming tasks, then perhaps some light may be shed on the results of Experiment 1 as well as those of past studies. Older adults who exhibit high levels of off-target verbosity are believed to be such a group. Off-target verbosity (OTV) is a phenomenon which is characterized by an abundance of speech which is irrelevant to the topic at hand (Gold, Andres, Arbuckle & Schwartzman, 1988). Levels of OTV have been found to be predicted by scores on measures believed to be associated with a decrease in inhibitory ability and frontal lobe functioning (Arbuckle & Gold, 1993; Pushkar Gold & Arbuckle, 1995; Arbuckle, LeClair, & Pushkar, 2000). Specifically, those with high OTV perform more poorly than those with lower levels of OTV on measures of switching between over-learned response sequences, interference and set-breaking. In contrast, performance on memory measures is unrelated to OTV, suggesting a specific decline in inhibitory and executive control processes (Arbuckle & Gold, 1993; Pushkar Gold & Arbuckle, 1995). The goal of Experiment 2 was to see how each negative priming task would relate to levels of OTV, as well as how they relate to other neuropsychological measures associated with frontal lobe functioning.

Experiment 2

In Experiment 2, older individuals who had been previously rated on verbosity level were selected on the basis of being high, mid, or low on the measure of OTV. These groups were administered the same negative priming tasks as in Experiment 1 in order to ascertain whether one or more of these tasks was able to differentiate among the OTV groups, and, if so, perhaps shed some light on the mechanism, or mechanisms, responsible for the NPEs found in Experiment 1.

Experiment 2 also assessed other cognitive abilities in an attempt to understand better the neuropsychological correlates of each negative priming task. Although somewhat exploratory in nature, it was believed that, if one or more of the NPEs related to other inhibition- associated measures, then some of the issues related to the current debate may be better illuminated. It was hypothesized that the negative priming task requiring the greatest processing would be related to measures known to be associated with frontal lobe functioning whereas the task requiring the least processing would not be related to those same measures.

Method

Participants

Participants were chosen on the basis of OTV factor scores that had been assessed in Phase 1 of a short-term longitudinal study. In Phase 1, 455 volunteers aged 65 and over were assessed for OTV. Participants were asked several close-ended questions about education, work history, financial status, and family related topics (e.g., How many years of education do you have?). The interview was recorded and then scored for OTV. Each response was scored two ways. First, if participants spoke about information which was not strictly related to the question asked, they would received a score of one 'out' for that item. The total number of outs across all questions was then divided by the total number of questions asked yielding a measure of 'Item Verbosity'. Second, the extent of unrelated information given for each question was scored on a scale from 1 to 9, with 9 'extents' indicating the greatest amount of off-target speech. The total extent score across all questions was then divided by the total number of questions asked to yield a measure of 'Extent Verbosity'. These two OTV scores were highly related ($r = .76$) and were combined into an OTV factor score using principal components analysis (Arbuckle et al. 2000).

Participants in the current study were 148 older adults aged between 64 and 89 years ($M = 73.54$, $SD = 5.40$) with 4 to 21 years of education ($M = 13.2$ years, $SD = 3.14$). All were drawn from the sample of 204 seniors who had participated in Phase 2 of the longitudinal study. Selection for Phase 2 was based on Phase 1 OTV factor scores (z-scores) such that one-sixth of the sample was drawn from each of the top 15% ($z \geq .95$) and bottom 15% ($z \leq -.98$) of the range of OTV scores and the remaining two-thirds from the middle 50% ($-.68 \leq z \geq .52$). In Phase 3, the current study, all those in the extreme ranges were invited to participate while those in the mid range were recruited randomly to complete a sample of 150 individuals. Two of the participants were dropped because of health problems. There were a total of 29 participants in each of the High and Low OTV groups. Out of the remaining 90 participants in the Mid group, the 29 adults who were closest to the 50th percentile were chosen to be the Mid group thereby creating equal numbers of participants in each OTV group. These 87 older adults were aged between 67 and 89 years ($M = 73.6$, $SD = 5.4$). The groups did not differ in mean education level but, consistent with previous findings that OTV increases with age (e.g., Arbuckle & Gold, 1993), the High group ($M = 76.5$, $SD = 5.8$) was significantly older than the Mid ($M = 73.0$, $SD = 5.5$) and the Low ($M = 71.5$, $SD = 4.6$) groups, $F(2,84) = 6.16$, $p<.01$.

Negative Priming Tasks

The negative priming tasks and materials used in Experiment 2 were the same as those used in Experiment 1.

Cognitive Measures

Controlled Oral Word Association Test (Fluency Test; Benton & Hamsher, 1976). Participants are asked to produce verbally as many words as they can think of that begin with a specific letter in a one minute period of time. They are asked to exclude proper nouns, numbers and the same word with a different suffix. Three letters are given (CFL) for a total of three word lists. There are three scores: total score, consisting of a count of all acceptable words produced; total repetitions, consisting of all words which are duplicates of words previously given, and total unacceptable words. This test is considered to measure one's ability to organize verbal output in a significant way (Lezak, 1995) and as such can be seen as the ability to focus thought keeping interference at bay.

The Stroop Neuropsychological Screening Test (Stroop Test; Trenerry, Crosson, DeBoe & Leber, 1989). This test is made up of two conditions. The first condition requires that the color word itself be read from a list of 112 word list (e.g., if the word blue is printed in a green color making 'Blue' would be the correct response). The second requires the participant to name the color with which a color word is printed from a list of 112 color words (e.g., in the above example, 'Green' would be the correct response). The time difference between saying the color names versus reading the words is believed to be a measure of the efficiency in concentration (Lezak, 1995) and as such can be seen as a measure of inhibitory control.

Trail Making Test (Reitan & Davison,1974). This test is given in two parts: A and B. In part A, participants are required to draw a line as quickly as they can in order to connect successively numbered circles from one to 25. In part B, the same process is required except that there are 13 numbers and 12 letters to be connected successively, alternating between a number and a letter (e.g., a line is drawn from the 1 to the A to the 2 to the B and so on). Time to complete the task is measured for both parts A and B and the difference score (B – A) is used as a measure of how one deals with more than one stimulus at a time and how supple is the mechanism responsible for the shift between the two (Lezak, 1995). This test has been found to be positively related to OTV (Arbuckle & Gold, 1993).

Procedure

The procedure for all of the negative priming tasks used in Experiment 2 was the same as in Experiment 1. The Negative Priming tasks of Experiment 2 were administered in Phase 3 of the longitudinal study, whereas the neuropsychological measures had been given earlier. The Stoop Test and the Controlled Oral Word Association Test were administered during Phase 1 and the Trail Making Test was administered during Phase 2. In all Phases there were several other cognitive and psychosocial measures administered. Phase 2 was conducted a median of 5 months after Phase 1 (Range = 0 to 20 months) and, Phase 3 was conducted a median of 12 months after Phase 2 (Range = 2 to 21 months). Only the measures that are pertinent to the present thesis are presented here.

In Phase 3, the order of the three negative priming tasks was counterbalanced across participants, but the three were always administered as a block. The block itself could be done at various points within the overall sequence of Phase 3 tests. The neuropsychological measures were administered using the procedures specified in the test manuals. When all of the testing procedures were complete in each Phase, participants received an honorarium in the amount of 25 dollars and were thanked for their time.

<u>Results</u>

The alpha level for all analyses was set at .05. Trials in which either of two kinds of errors occurred were omitted from analyses.

<u>Error Analyses</u>

Means and standard deviations are given in Table 6. Equipment error rates for the Low OTV group ranged from 0.47% in the Letter Control condition to 1.7% in the Time Control condition. Equipment error rates for the Mid OTV group ranged from 0.26% in the Diamond Control condition to 2.6% in the Time Negative Priming condition.

Table 6. Means and Standard Deviations for Participant and Equipment Errors on the Three Negative Priming Tasks as a Function of OTV Group.

OTV Group		Condition						
			Letter		Diamond		Time	
		Single	Control	NP	Control	NP	Control	NP
		Equipment Errors						
Low	M	0.31	1.69	0.34	0.31	0.55	0.76	0.59
	SD	0.71	4.87	0.67	0.60	0.69	1.27	0.98
Mid	M	0.79	1.00	1.28	0.14	0.52	1.38	1.03
	SD	1.93	1.95	2.48	0.44	0.74	2.08	1.67
High	M	0.90	1.77	0.40	0.37	0.80	0.83	0.83
	SD	4.01	5.54	1.13	0.72	0.76	1.34	1.09
		Participant Errors						
Low	M	0.10	0.97	1.38	0.52	1.10	1.38	2.10
	SD	0.41	1.12	1.70	0.91	1.26	1.15	1.97
Mid	M	0.24	0.83	1.10	0.58	0.93	2.21	2.55
	SD	0.51	1.19	1.35	0.73	1.13	2.04	2.52
High	M	0.20	1.40	1.37	0.47	1.00	3.06	3.46
	SD	0.48	1.73	1.54	0.63	1.23	3.27	2.70

Note: NP = Negative Priming

Equipment error rates for the High OTV group ranged from 0.63% in the Letter Negative Priming condition to 2.1% in the Diamond Negative Priming condition. Analyses performed on equipment error rates showed no significant OTV or condition effects, alone or in interaction, in the Letter, Diamond or the Time task. All $\underline{F}$s $(1,60) < 2.4$; $\underline{p} > .05$.

Participant errors committed by the Low OTV group ranged from a rate of 0.2% of the Letter control trials to 4.8% of the Time negative priming trials. The Mid group's error rate ranged from 0.4% of the Letter control trials to 6.3% of the Time negative priming trials. The High group committed participant errors at a rate ranging from 0.3% of the Letter control trials to 7.9% of the Time negative priming trials. Analyses performed on error rates showed no significant main effect of OTV group, condition or interactions in the Letter task, a significant main effect of condition on the Diamond task ($\underline{F}(1,85) = 17.63$, $\underline{p} < .001$) and a significant main effect of both OTV group ($\underline{F}(2,85) = 3.92$, $\underline{p} < .05$) and condition ($\underline{F}(1,85) = 4.19$, $\underline{p} < .05$) on the Time task. Within both Comparative Judgment tasks, there were more subject errors committed in the negative priming conditions than in the control conditions. As well, both the Mid and High OTV groups committed more errors in the Time task than did the Low group. As in Experiment 1, when those committing more than five subject or equipment errors on either the control or the negative priming condition (13 individuals) were removed from the main reaction time analyses described below, there were no differences in the results. Therefore, all participants were included in all the analyses.

Reaction Time Analyses

A 3 (OTV group) x 3 (condition) between-within ANOVA was performed on the Letter task data using mean RTs (see Table 7). There was a significant main effect of condition $F(2, 168) = 51.81$, $p < .001$, but not of OTV group $F(2, 84) = 1.23$, ns. As well, there was no OTV group by condition interaction $F(4, 168) = 2.10$, ns. As can be seen from Table 7, the condition effect was attributable to an interference effect, but not a NPE. Overall, participants were slower on the control condition than on the single letter condition by 17ms, indicating an interference effect. None of the groups showed a significant difference between the control condition and the negative priming condition.

A 3 (OTV group) x 2 (condition) between-within ANOVA was performed on the mean RTs of the Diamond data (see Table 8). There were no significant differences among the OTV groups on overall RTs, $F(2,83) = 1.66$, ns. There was a significant main effect of condition $F(1, 83) = 93.86$, $p < .001$, indicating an overall NPE. The OTV group by condition interaction was not significant, indicating that the NPE was equivalent for the three groups $F(2,83) = 0.60$, ns. All three OTV groups showed a NPE with the Low group showing an 81ms effect, the Mid group showing a 63ms effect and the High group showing a 56ms effect.

A 3 (OTV group) x 2 (condition) between-within ANOVA was performed on the mean RTs of the Time data (see Table 8). There was a significant main effect of OTV group, $F(2, 84) = 5.35$, $p < .01$, with the High OTV group having longer RTS than the Mid or Low groups. There was also an effect of condition, $F(1,84) = 124.08$, $p < .001$, with RTs being longer in the negative priming condition than in the control condition. However, as can be seen in Figure 4, both effects were qualified by a significant OTV group by condition interaction, $F(2, 84) = 5.52$, $p < .01$, with the High group showing a

Table 7. Means and Standard Deviations (MS) for the Three Letter Task Conditions, the Interference Effect and the Negative Priming Effect as a Function of OTV Group.

Experiment 2

		Conditions			Effects	
OTV Group		Control	Interference	NP	Interference	NPE
Low						
	M	236.5	248.2	250.3	11	2
	SD	56.6	63.1	49.8		
Mid						
	M	243.1	259.0	268.9	16	10
	SD	58.6	66.4	68.6		
High						
	M	253.8	275.8	277.6	23	2
	SD	51.2	60.5	57.9		
Overall						
	M	244.4_a	261.0_b	265.6_b	17	5
	SD	55.3	63.7	59.7		

Note. Overall means with different subscripts differ significantly (t-tests at a Bonferroni corrected probability of $p < .01$). NP = Negative Priming. NPE = Negative Priming Effect.

Table 8. Means and Standard Deviations for the Comparative Judgment Time Task and the Comparative Judgment Diamond Task as a Function of OTV Group.

Group		Control Condition	NP Condition	NPE
		Diamond Task		
Low				
	M (SD)	730.2 (154.8)	811.4 (231.4)	81 [a]
Mid				
	M (SD)	715.4 (126.1)	778.4 (159.8)	63 [a]
High				
	M (SD)	785.5 (108.3)	841.8 (157.7)	56 [a]
		Time Task		
Low				
	M (SD)	1092.6 (124.2)	1190.9 (130.5)	98 [a]
Mid				
	M (SD)	1036.7 (152.4)	1146.3 (192.8)	109 [a]
High				
	M (SD)	1176.5 (184.1)	1346.0 (301.6)	244 [b]

Note. NPEs with different subscripts for each OTV group differ significantly (t-tests at a Bonferroni corrected probability of $p < .01$). NP = Negative Priming. NPE = Negative Priming Effect.

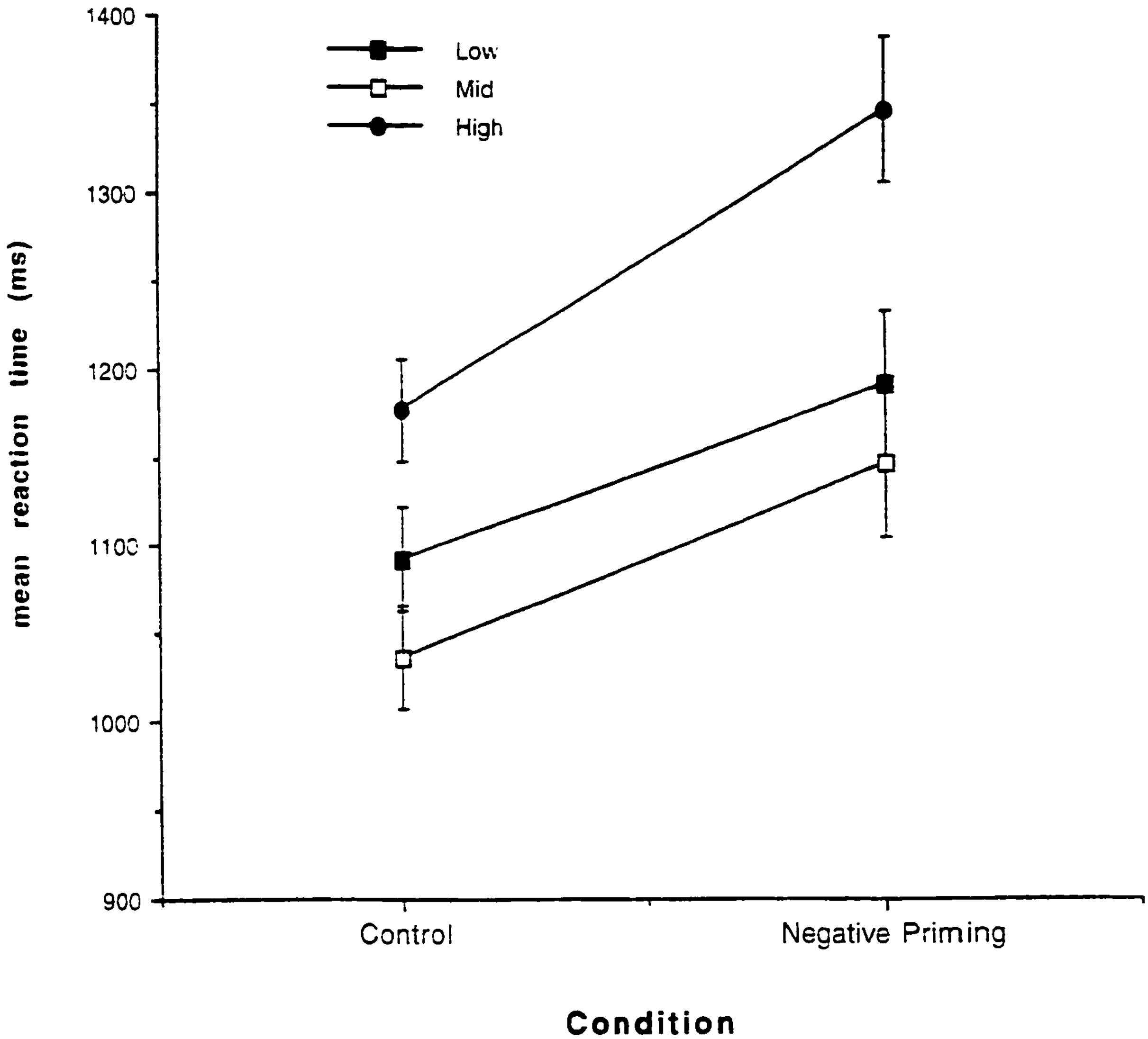


Figure 4. Mean reaction time and standard errors for the Time task as a function of OTV group and condition.

significantly greater NPE (244ms) than both the Low (98ms) and the Mid (109ms) groups.

Correlational Analyses

In order to have the full range of OTV scores, the data from all 148 participants was used. A factor considered to represent inhibitory control was constructed using responses to the Stroop Test, the Benton Total Acceptable Words and the Trail Making test in a Principal Components Analysis. Each measure loaded on the factor as follows; the Benton (-.63), Trail Making (.80) and, Stroop (.73). The resulting eigenvalue was 1.58, extracting a total of 52.6 percent of the associated variance. Higher scores on the inhibition factor indicated poorer performance. This variable was used as the inhibition measure in the correlational analyses. These analyses were done across the three OTV groups.

As Table 9 shows, the NPEs of the three tasks were not significantly correlated with each other nor were they correlated with age. The only significant correlation with interference was a significant negative correlation between the Interference effect and the Letter NPE. The only significant correlation with inhibition was the positive correlation between Time NPE and the Inhibition factor with larger NPEs associated with poorer inhibitory control (higher scores on the factor means poorer inhibitory control).

Post Hoc Analyses

Because of the large NPE found in the High OTV group for the Time task, the results of Experiment 2, like those of Experiment 1, were not wholly consistent with either the inhibitory deficit hypothesis or the episodic retrieval hypothesis. To attempt to

Table 9. Correlations Among All Negative Priming Effects and All Other Variables (n = 148).

	Negative Priming Variables		
Variables	Letter NPE	Time NPE	Diamond NPE
Time NPE	-.04		
Diamond NPE	.05	.08	
Letter Interference	-.40*	.00	-.06
Age in Years	.01	-.03	-.10
Inhibition Factor	-.05	.20*	-.10

* $p < .05$

clarify matters, levels of processing were assessed within each task for each experiment using a procedure similar to that of Jacoby, Craik and Begg (1979). In their study participants were asked to judge the difference in size between two common nouns (e.g., goat-horse). They found that the closer the objects were in size the more likely participants were to recall those nouns in an unexpected memory test. They argued that deeper levels of processing took place when more analysis was needed to make the judgments, leading to better encoding and thus better memory for the items.

Using the idea behind the Jacoby et al. (1979) study, it seemed possible to assess levels of processing and its effects on negative priming within both the Time task and the Diamond task. Unfortunately, the tasks in the present study were not set up with this analysis in mind, so participants' individual scores could not be used in the analysis. However, following a technique used by Clark (1973), mean reaction times for each prime probe trial were used as "participants", that is, "items" rather than "participants" became the unit of analysis. For the Diamond task, each trial, probe and prime, was given the following 'data': (a) the mean reaction time for response to the probe; (b) a score representing the font size difference between the members of the prime pair (e.g., if the target was in a 12-point font and the distractor was in an 18-point font, the item would receive a score of 6); (c) a font size difference score for the probe pair and (d) a grouping code (1 = control condition; 2 = negative priming condition). The same procedure was used for the Time task except that the score each prime and probe received was based on the distance between times on an ordinal scale. For example, if the two words in one pair were 'minute' and 'second', then that pair was given a score of 1. A score of 1 would also be given if the two words were 'day' and 'week' as there was no other time period between these two periods. A score of 7, the highest possible score, was given if the two words were 'decade' and 'second' as these two time periods were 7 periods away from each other. This technique allowed for an assessment of the overall effect of levels of processing on mean probe response times and an assessment of the effect of processing level by condition within each category of participants. Thus, five separate analyses were done, two for the participant groups from Experiment 1 (young and old) and three for those from Experiment 2 (Low, Mid and High).

Prior to doing the analyses of variance, correlations were calculated between probe reaction times and distance of prime and probe pair members on the Diamond and Time scales. As can be seen in Table 10, for the Time task, probe pair distance was significantly and negatively related to probe reaction time for all five participant groups, indicating that shorter distances slowed RTs. In contrast, prime pair differences were related to probe reaction times only for the Mid group and the relationship was positive. For the Diamond task, with the exception of the young group, probe pair differences in font size were significantly and negatively related to probe reaction times, whereas there were no significant relations between prime pair differences and probe reaction times.

Because of the large negative correlations found between the probe RTs and distances of probe pair members on the relevant scales, a series of ANCOVAs (two per group) were performed using probe font size difference as a covariate for the Diamond task and probe time difference for the Time task. Condition was the between items variable (control vs negative priming) and mean RT per probe was the dependent variable. Prior to the ANCOVAs, a series of unadjusted t-tests were done to assess whether the NPEs observed in the two tasks were still obtained when items, not

Table 10. Correlations Among Mean Font Size Differences and Time Differences on Primes and Probes as a Function of Group (Experiment 1 and 2).

	Font Differences		Time Differences	
Age Group	Prime	Probe	Prime	Probe
Experiment 1				
Young				
Mean Probe RT	-.01	-.22	.16	-.65***
Older Adults				
Mean Probe RT	-.07	-.38*	.09	-.65***
Experiment 2				
OTV Group				
Low				
Mean Probe RT	.05	-.42**	.18	-.56***
Mid				
Mean Probe RT	.10	-.44**	.32*	-.63***
High				
Mean Probe RT	.21-	-.38*	.23	-.54***

* p < .05; ** p <.01; *** p < .001

participants, were the units of analysis. For the Diamond task, all groups with the exception of the High OTV group data and the young group data showed a significant difference between conditions on the t-tests. However, when the covariate was entered for each group, there were no significant NPEs. That is, the covariate in each analysis explained enough variance to wipe out the NPEs when items were the units of analysis. For the Time data however, the t-tests showed significant NPEs for all groups before the covariate was added, and the NPE remained significant after adjustment for probe time difference except in the young group. In the young group, the condition effect was gone after inclusion of the covariate.

Discussion

Overall, a similar pattern of results emerged in Experiment 2 as had been found in Experiment 1. All three groups showed a NPE in both the Time task and in the Diamond task, however, in the Time task, the High OTV group showed a larger NPE than the Mid and Low groups. No OTV group showed a NPE for the letter task. The correlational results from Experiment 2, like those from Experiment 1, show individual inconsistency with respect to the degree of decline, or lack thereof, as measured by the different NP tasks. Those who exhibit greater effects in the Time task do not necessarily show the 'least' or 'greater' effect in the Letter or Diamond tasks.

In the Time task, the average NPE across the three groups was 150ms, which is comparable to the 139ms for the older group in Experiment 1. The High OTV group however showed a far greater magnitude of NPE (244ms) than did either the Low (98ms) or the Mid (109ms) groups. This finding gives some insight into the NPE shown in the Time task and therefore, perhaps the effect resulting from deeper levels of processing. If individuals with higher levels of OTV also show a greater NPE, then the demands of the Time task may be forcing the use of a system related to OTV, whereas the demands made by both the Letter and Diamond tasks do not require access to the same system in order to respond. Support for this argument lies in the fact that the inhibitory factor, made up of 'frontal measures', related in the expected direction to the NPE for the Time task and not to the NPEs for the other two tasks. This relationship makes sense if we assume that there are several possible combinations of cortical systems that could be used depending on the demands of the task. The Diamond task and the Letter task are more perceptual in their demands than is the Time task, which has a semantic load. It is interesting to note, that while there was no significant interaction between OTV group and condition for the Diamond task, the effects were in the opposite direction to those found in the Time task. That is, the largest effect was seen in the Low group (81ms), then in the Mid group (63ms), with the lowest effect found in the High group (56ms). The perceptual demand made by the Diamond task may rely upon the posterior system rather than the anterior one.

It may be that those with inhibitory deficits also have more difficulties with respect to their episodic retrieval mechanism. The question is what is episodic retrieval and why would the High OTV group be more affected by it? It may be that episodic retrieval is a measure of interference, with greater processing demands resulting in more interference. Perhaps interference develops to a greater or lesser extent, at the level of the probe. This interference may be happening during the probe as a result of the conflict between the previous 'do not respond' tag, placed during the prime and now retrieved on the probe, and the current need to place a 'respond' tag onto the same information. How much interference is involved may be associated with the level at which the stimuli were processed, with deeper processing creating more interference than shallower processing. Possibly, negative priming, in all cases, is a measure of episodic retrieval and interference. Perhaps at shallow processing, as in the Letter task, a 'weak' 'do not respond' tag is given to the distractor, at a deeper level of processing a 'strong' tag is given, and at the deepest level of processing, a 'super' tag is given. Older individuals, whose memory is compromised and who are more susceptible to interference, as compared to younger adults, will show a greater variation in effects, depending on the strength of the tag. In the case of shallow processing, the old are not affected by negative priming because there is minimal interference, the 'weak' tag being too weak to be remembered at the time of the probe. At deeper levels of processing, all ages will be equally affected by the amount of interference resulting from the 'strong' tag because the strong tag is remembered by everybody. But, at the deepest level of processing, the 'super' tag, causing the most interference, affects older individuals to a greater extent because they already have greater susceptibility to interference, and bypassing the interference created by this tag will be more difficult than getting by tags of a lesser strength.

The post hoc analyses have shed some light on the nature of processing level. We can see from the strong negative correlations between the probe stimulus time difference and mean probe RTs, and the significant, but not as strong, negative correlations between the probe font differences and mean probe RTs for the Diamond task that performance on both tasks is affected by these within-task variations in processing demands. However, the fact that only in the Time task did the NPEs remain after controlling for different levels of processing, (i.e., different degrees of closeness of probe pair members on the time continuum), gives pause for thought. The Time task may be a 'purer' measure of inhibition or episodic retrieval or even a combination of these mechanisms because, while its effect is susceptible to variation in levels of processing within task, the resulting NPE occurs despite this susceptibility. It is of note that for the most part it was the level of processing of the probe which related to probe RT as opposed to the level of processing in the prime. This indication that the effect appears to be happening at the probe level is more consistent with the episodic retrieval hypothesis, which postulates that the effect in the negative priming paradigm occurs at the probe level.

One problem with interpretation of the post hoc results is that Experiment 1 and 2 were not initially designed to address within-task levels of processing. In fact, the closeness of items on the continuum was not either manipulated or controlled, and it was discovered only afterwards that, due to all the constraints in setting up negative priming pairs for a comparative judgment task, the pair members in the negative priming condition in the Diamond and Time tasks were, on average, closer together than were those in the control condition. Previous studies with comparative judgment tasks did not control for this variable, and it was only after the post hoc analysis, that its importance was recognized. The NPE itself remained, even after controlling for this variable, in the Time task but not in the Diamond task. The goal of Experiment 3 was to take a more systematic look at within task level of processing that avoided any confound with condition.

Experiment 3

In Experiment 3, a different set of stimuli was used from that used in Experiments 1 and 2. Within task manipulations allowed the further assessment of the levels of processing hypothesis. This third experiment was based on the post hoc results from Experiment 2, the levels of processing hypothesis of Jacoby et al. (1979), and the methodology developed for an Honors thesis conducted by Fabi (2000). The study was carried out as an Honors thesis project by Georgescu (2001) with the assistance of Chow, and was co-supervised by the present author and her advisor.

Like the Time and Diamond tasks, the task used for Experiment 3 required comparative judgments, in this case comparisons of size using animal pictures as stimuli. Besides the age group comparison and the control and negative priming conditions, two additional two-level factors were manipulated. The first was the presentation of the animal pictures in 'real' relative size (e.g., the elephant picture was larger than the bird picture) versus presentations of the animals in the 'same' size (e.g., the elephant picture was the same size as the bird picture). This manipulation was intended to cause two levels of processing with greater amounts required for the same size presentation. The real size condition was intended to require only a perceptual analysis, as the actual size of the pictures reflected the real size differences of the animals. The same size condition was designed to require a semantic level of processing because the pictorial representation no longer allowed a simple perceptual analysis. Rather, one had to reach a semantic analysis to make the necessary judgment. The second manipulation was the closeness of the animals in nature with the two conditions consisting of comparing animals that were adjacent or nonadjacent on a continuum of natural size. These conditions were also believed to require two levels of processing, with the adjacent condition requiring more processing than the non adjacent condition. The hypothesis was that older adults would be more affected by these levels of processing manipulations than young adults would be. Thus, at the deepest levels (same size, adjacent), older adults would show larger NPEs than younger adults whereas the reverse would be true at the shallowest levels (real size. nonadjacent).

Method

Participants

Forty-nine older adults (aged between 60 and 90 years, (M = 71.94, SD = 7.12) and 50 young adults (aged between 18 and 35 years,(M = 22.56. SD = 3.85) participated in the study. Older participants had a mean education of 15.39 years (SD = 3.21, range of 11 to 24). Younger adults had a mean education of 14.92 years (SD = 1.93), range of 11 to 21). All participants were screened for proficiency in English and major health problems. As well, participants were naïve with respect to the contents of the study. Older participants were recruited via a participant pool of older community dwelling adults as well as by word of mouth. Young participants were recruited via presentations in Introduction to Psychology courses at Concordia University and through posters placed in the halls of Concordia University, advertising the study. All participants received an honorarium of $8 with older adults receiving an additional $4 to cover travel to the campus.

Negative Priming Task

Comparative Judgment Animal Task. In this task the stimuli consisted of pictures of eight animals, each one a different natural size. The animals from smallest to largest were ladybug, butterfly, bird, cat, wolf, zebra, camel, and elephant. The participant was presented with two animal pictures and asked to call aloud the name of the larger animal as quickly but also as accurately as possible. For example, if the 'cat' was presented with the 'camel', then 'camel' would be the correct response. Animals were depicted in black and white and were presented in two ways. The first was the Real Size condition. The animals were portrayed in their real relative sizes. For example, the bird was shown as being smaller than the cat but bigger than the ladybug and so on. The second was the Same Size condition. Here, all the animals were shown as being the same size. The pictured size of the elephant was equal to that of the wolf, ladybug, and all other animals (see Appendix A for sample stimuli and lists). Within each of the size conditions were the Control and Negative Priming conditions of which there were 24 control trials and 24 negative priming trials. Trials were presented in three blocks of 19 prime-probe trials. The first three prime-probe trials were fillers and were not counted; the last 16 trials were eight control trials and eight negative priming trials in a nonsystematic sequence. Embedded in the last 16 trials was an 'adjacent' and a 'nonadjacent' condition. Trials where the two animals in the pair were next to each other on the natural size continuum were considered adjacent, while pair members that were further apart on the continuum were considered nonadjacent. For example, if the ladybug were paired with the butterfly, the pair was adjacent in size, whereas if the ladybug were paired with the bird or cat, the pair was nonadjacent. Within each block, four of the eight probe pairs for the control trials and four of the eight probe pairs for the negative priming trials were in the adjacent condition, while the other four probe pairs of each type were nonadjacent. Nonadjacent probe pairs were 2 or 3 spaces apart on the continuum, e.g., ladybug-cat. With respect to prime pairs, approximately one-third of them on each list were adjacent and the remaining two-thirds were nonadjacent (2 to 4 spaces apart). The distance between the two pair members on the animal size continuum was matched between negative priming and control trials so that the size differences did not differentially affect the negative priming and control conditions. For example, if on a given negative priming trial, the distance apart was three on the prime pair and one on the probe pair, there would be a matching control trial within the same block with the same prime and probe pair distances. The position (left or right) of items in pairs was counterbalanced so that a given picture appeared approximately equally often in the left or right position. Negative priming pairs were strictly counterbalanced in terms of prime and probe and, right and left positions. Excluding negative priming trials, the repetition of individual pictures was controlled such that there was always at least one other pair intervening before a picture was repeated. To encourage participants to process the Real Size pairs perceptually rather than semantically, the three Real Size blocks were always presented first, followed by the three Same Size blocks. The difference in RT between the Control condition and the Negative Priming condition was used as the measure of the NPE.

As with the previous Negative Priming tasks, The Comparative Judgment Animal task was programmed on a Macintosh LC630 computer using Psyscope 1.0. (Cohen, et al., 1993). Stimuli were presented on an Apple Multiscan 20 Display monitor. Voice activation and measurement of reaction time in milliseconds was performed by the Psyscope Button Box using a clip-on Sony high impedance ECM-909A microphone.

Procedure

Each participant was tested individually. A consent form was given to the participant to read and to sign and demographic information was gathered. Several measures which were related to Georgescu's (2001) Honors thesis were administered but only the negative priming task will be presented here.

The procedure was similar to Experiments 1 and 2. The sequence of events was as follows. Each block of trials started with the presentation of a fixation point (+) in the middle of the screen for 500ms. A pair of animals was then presented on the screen (prime). The pair remained on the screen until the participant responded. The time in ms from the onset of the animal pair to the response was recorded (prime reaction time). A blank screen immediately followed the response and remained blank for 500ms. The fixation point was again presented for 500ms followed by the second animal pair (probe). The animal pair remained on the screen until the participant responded. The time (in ms) from the onset of the animal pair to the response was recorded (probe reaction time). The screen went blank for 500ms following the probe response. The experimenter recorded any errors made by the participant or by the equipment.

Instructions for the Real size condition were always given first. Participants were shown the pictures of the eight animals, arranged in order of size, and asked to name the animals. If the label they gave was different from the intended one (e.g., they said "dog" instead of "wolf"), their label was accepted and used throughout the study. They were then given the instructions for the Real Size condition, which were to name aloud the bigger animal of each pair. After the participants had seen some practice items and then done the three blocks of the Real Size condition, they were told that they would now be presented with the same animals, but that they would all be shown in the same size on the screen. They were then shown an example of a same size bug and zebra. To ensure the understanding of the new task, participants were told that "Your task is to say aloud the one that is bigger in reality, that is, the zebra".

At the end of the experiment participants were thanked and paid for their participation. Any questions participants had were answered.

Results

The alpha level for all analyses was set at .05. Trials on which either participant or equipment errors occurred were omitted from analyses.

Error Analyses

As can be seen in Table 11, equipment error rates occurring during younger subject testing ranged from 0.8% in the Same Size Control to 3.0 % in the Real Size Negative Priming condition. Equipment error rates for older adults ranged from 1.6 % in both Real Size conditions to 3.6 % in the Same Size Negative Priming condition. Analyses performed on mean equipment errors showed no significant age or condition effects, alone or in interaction A significant condition by size interaction was found, $F(1,97) = 8.98$, $p < .05$, and a significant condition by size by age group interaction, $F(1,97) = 5.13$, $p < .05$, with more equipment errors occurring in the Real Size Control condition for younger adults than in the Real Size Negative Priming Condition. Older participants did not differ on this combination of conditions. No one individual had more than 5 errors.

Participant errors made by younger adults ranged from a rate of 0.2 % in the Real Size Negative Priming condition to 6.5% in the Same Size Negative Priming. Participant error rates made by older adults ranged from 1.6% in the Real Size Control condition to 6.8% in the Same Size Negative Priming condition. Analyses performed on mean

Table 11. Means and Standard Deviations for Participant and Equipment Errors on the Comparative Judgment Animal Task as a Function of Age Group.

Age Group		Real Size Control	Real Size NP	Same Size Control	Same Size NP
		Equipment Errors			
Young	M	0.36	0.16	0.10	0.34
	SD	0.72	0.55	0.30	0.59
Old	M	0.31	0.31	0.41	0.47
	SD	0.58	0.51	0.64	0.79
		Participant Errors			
Young	M	0.26	0.24	0.46	0.78
	SD	0.56	0.51	0.67	1.05
Old	M	0.27	0.37	0.51	0.83
	SD	0.63	0.78	0.71	0.89

Note. NP = Negative Priming.

participant errors showed no significant age or condition effects, and no interactions involving either of these variables. The main effect of Size was significant $F(1,97) = 44.45$, $p < .05$, with the Same Size condition having more participant errors than the Real Size condition. No one individual had more than 4 participant errors occur during testing. When the one individual committing four participant errors was removed from the main reaction time analyses described below, there were no differences in the results. The same technique was done removing the one participant who had four equipment failures, and again, there were no differences in the results. There were no individuals who had a high number of both types of errors. Therefore, all participants were included in all the analyses.

Reaction Time Analyses

A 2 (age) x 2 (condition) x 2 (size) between-within ANOVA was performed on the Comparative Judgment Animal task data using mean RTs (see Table 12). Older adults had longer RTs than younger adults, $F(1, 97) = 35.08$, $p < .001$, RTs were slower in the negative priming condition than in the control condition, $F(1, 97) = 45.56$, $p < .001$, and RTs were slower in the Same Size condition than the Real Size condition, $F(1, 97) = 360.96$, $p < .001$. These main effects were qualified by a significant age by size interaction, $F(1, 97) = 6.22$, $p < .05$), and a significant condition by size interaction, $F(1, 97) = 12.04$, $p < .01$. As can be seen in Figure 5, older adults took longer to respond in both size conditions but this difference was greater in the Same Size condition (mean difference = 212.361; $SE = 34.83$) than in the Real Size condition (mean difference = 166.96; $SE = 31.68$). As can be seen in Figure 6, overall, the difference between the RTs in the negative priming condition and those in the control condition was greater for the

Table 12. Means and Standard Deviations (SD) for the Comparative Judgment Animal Task as a Function of Age Group and Size Condition.

Age and Size		Control	NP	NPE
		Condition		
Real Size				
Young				
	M	805.6	827.5	21.9
	SD	(128.9)	(132.9)	
Old				
	M	967.7	999.3	31.6
	SD	(175.7)	(199.0)	
Same Size				
Young				
	M	944.7	988.8	44.1
	SD	(141.5)	(148.6)	
Old				
	M	1145.8	1212.4	66.6
	SD	(196.8)	(213.7)	

Note. NP = Negative Priming; NPE = Negative Priming Effect

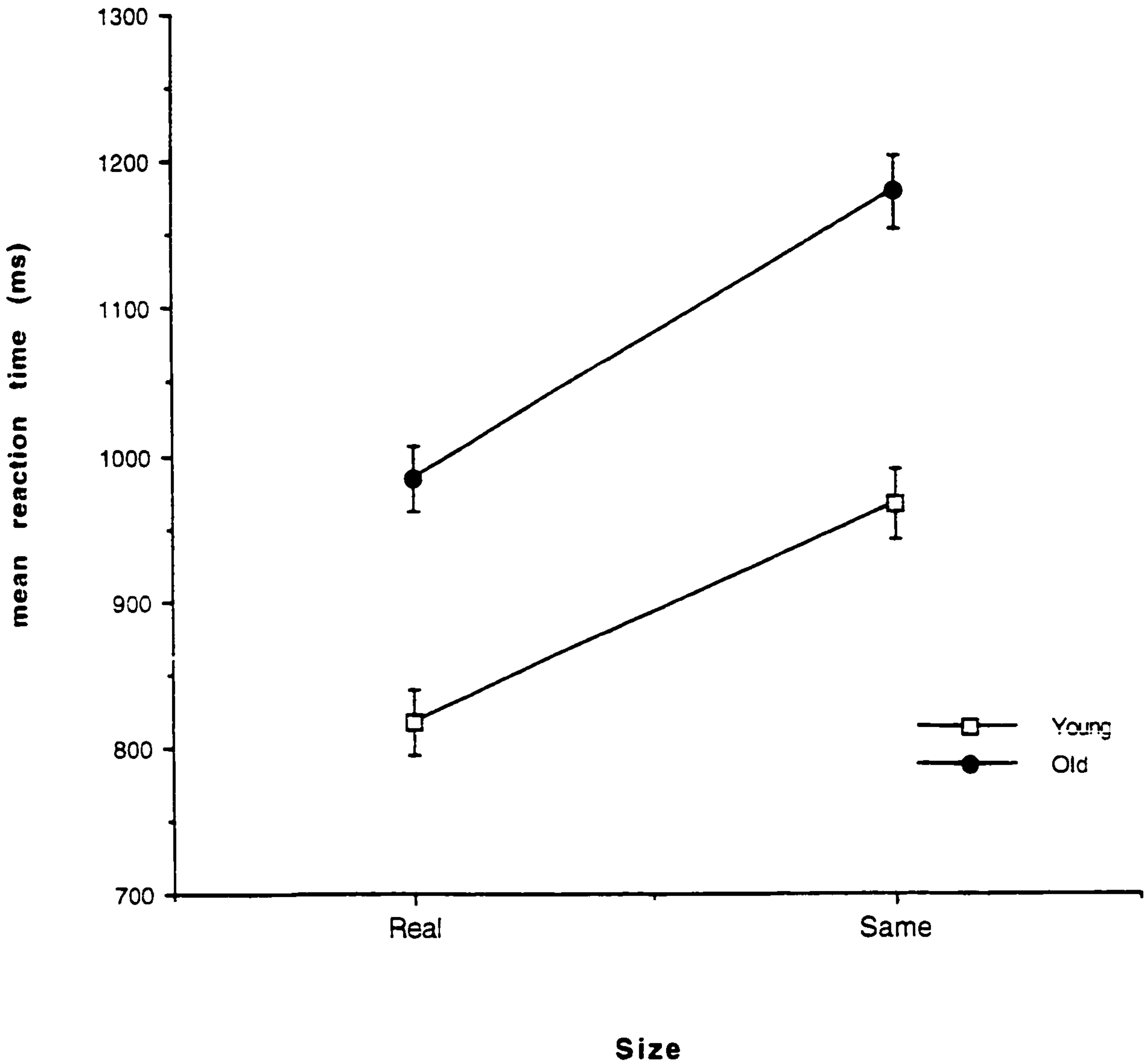


Figure 5. Mean reaction time and standard errors for the Animal task as a function of age and size.

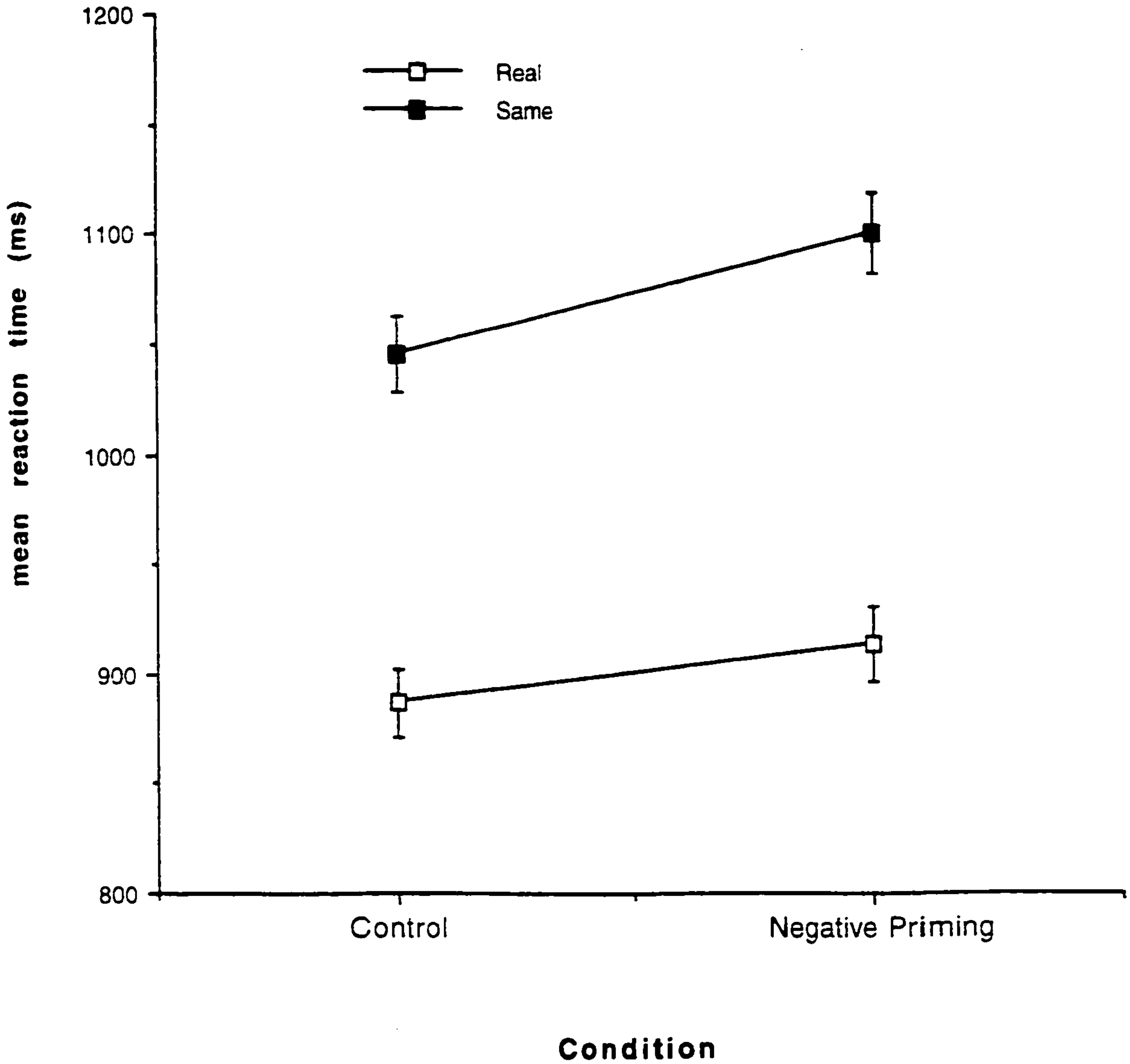


Figure 6. Mean reaction time and standard errors for the Animal task as a function of condition and size.

Same Size condition (mean difference = 55.34; SE = 7.54) than for the Real Size Condition (mean difference = 26.77; SE = 7.15). There was no significant interaction for age by condition, $F(1,97) = 1.75$, ns, or for age by condition by size, $F(1,97) = .60$, ns, which means that the age groups did not differ significantly in size of the NPE for either task.

A 2 (age) x 2 (size) x 2 (spacing) between-within ANOVA was performed on the Comparative Judgment Animal task NPEs. There was a significant main effect of spacing, $F(1, 97) = 86.96$, $p < .001$, and size, $F(1, 97) = 8.52$, $p < .01$, but not of age, $F(1, 97) = 2.30$, ns. The NPEs were larger for the adjacent condition and for the Same Size task. As can be seen in Table 13, the effect of spacing was qualified by a significant age by spacing interaction, $F(1, 97) = 5.69$, $p < .05$). As can be seen from Figure 7, the older adults showed a greater NPE under the adjacent condition than did younger adults, but young and old showed equal effects under the nonadjacent condition. There were no significant interactions for age by size, $F(1,97) = 0.42$, ns, spacing by size, $F(1,97) = 0.90$, ns, or spacing by size by age, $F(1,97) = 1.30$, ns.

Discussion

The results with respect to levels of processing that emerged in Experiment 3 were similar to those found in Experiments 1 and 2. The two age groups had equal NPEs and these NPEs were greater for the same size condition than for the real size condition. Overall, the NPE shown by older adults did not exceed that of the young, however, older adults did show a greater effect than younger adults under the adjacent condition.

Table 13. Means and Standard Deviations in Milliseconds for the Negative Priming Effects on the Comparative Judgment Animal Task as a Function of Size, Age Group and the Spacing.

		Size Condition	
Age and Condition		Real Size	Same Size
Adjacent			
Young			
	M	65.9	75.9
	SD	(80.3)	(103.7)
Old			
	M	96.2	136.3
	SD	(124.8)	(136.6)
Nonadjacent			
Young			
	M	-21.1	3.8
	SD	(59.9)	(81.8)
Old			
	M	-25.3	-10.6
	SD	(102.7)	(94.0)

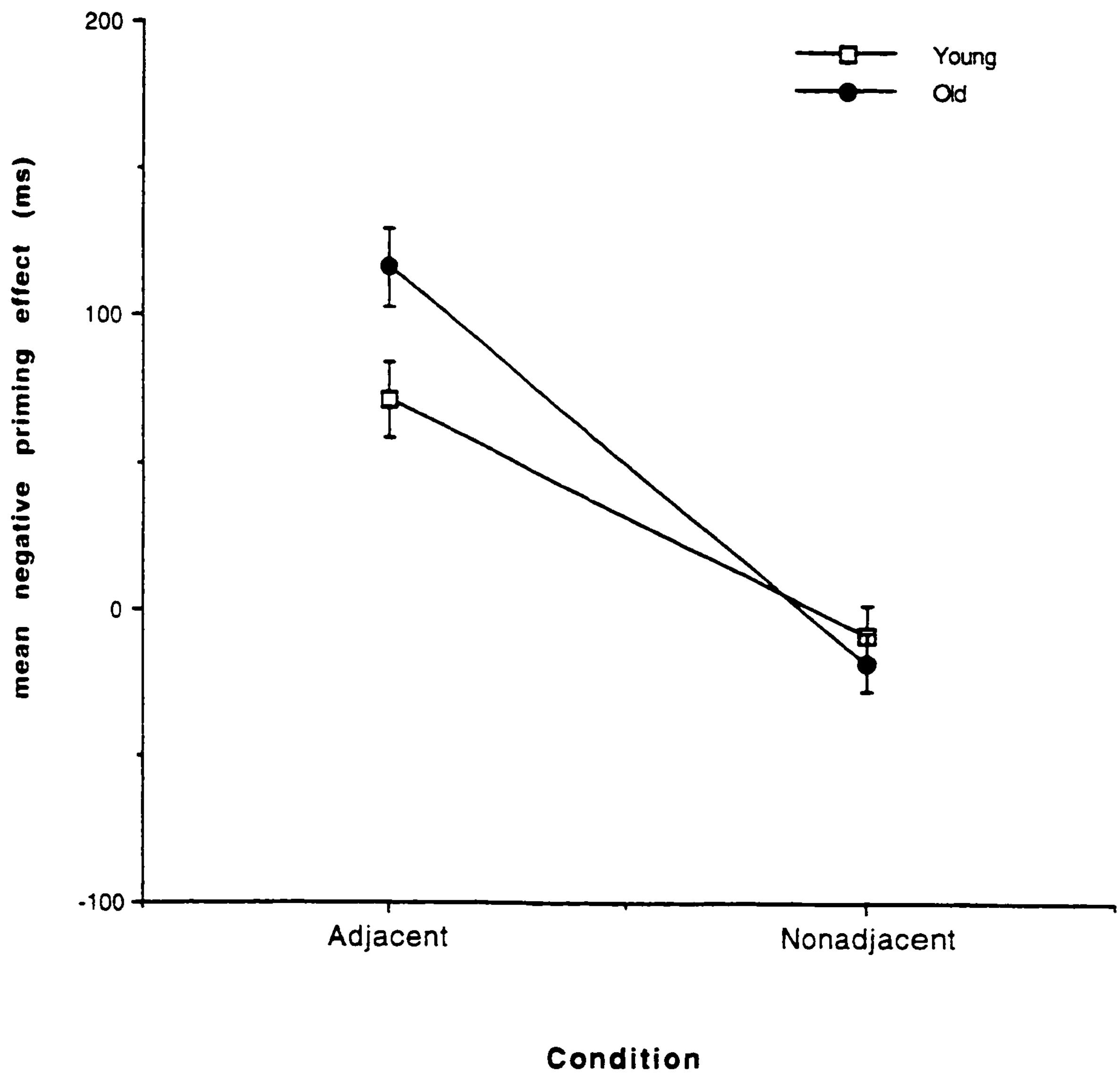


Figure 7. Mean negative priming effect and standard errors for the Animal task as a function of age and spacing.

The NPE produced by the semantic versus perceptual analysis, as measured by the same versus real size conditions, affected both age groups equally. Older adults were not more affected by this manipulation as may have been expected given the results of the Letter and Diamond versus Time tasks from Experiment 1. Re-examination of the NPE data showed that the NPE for the older group with the Time task in Experiment 1 (140ms) was almost double the NPE for the older group within the Same Size condition in Experiment 3 (66ms). For the young groups, the difference between these effects was essentially non existent (47ms and 44ms respectively).

There are at least three possible reasons for why the Same Size condition of Experiment 3 did not produce a bigger NPE. The first is that the Same Size condition was always done after the Real Size condition because of a concern that, if it were done first, participants would analyze the following Real Size stimuli semantically, rather than perceptually. The problem with always having the Same Size condition second, however, was that participants were able to 'practice' and become familiar with the animals and their respective sizes prior to doing the Same Size condition. This practice may have resulted in less need for semantic analysis than would have been the case had the same size condition been administered first, or better still, on its own using a between-subjects design. The second possible reason is that the difference between an analysis based on words (Time task) and that of one based on pictures (Animals task) may have had more of an effect on processing depth than was first believed. There may be more 'work' to do when information is presented in a word format than when it is presented as pictures. The slower RTs to same size pictures suggest that they needed deeper processing than the real size pictures, but the picture format may have required less processing than had the animals been presented in word format, as were the Time task items. The third possible explanation is that the judgment of size relies on the analysis of physical attributes whereas the judgment of length of time is more abstract. These two kinds of comparison can be seen as qualitatively different and this difference may affect the old more than the young. Any of these three possible explanations could have resulted in less processing depth than was first believed would occur and, less processing depth than that required by the Time task. It may be that the depth, at which the stimuli in Experiment 3 were actually processed, was not deep enough to cause older individuals more difficulty than the difficulty caused for the young, thus, both age groups showed equal NPEs.

Level of processing, as measured by closeness on the continuum of size, seemed to affect older individuals to a greater extent than it did younger adults. The results of the post hoc analysis of the data from Experiment 1 and 2 showed that the young were not affected by this same kind of processing manipulation in the Diamond task, as seen by the nonsignificant correlation between closeness in size and probe RTs, whereas, for older adults, this relationship was significant. The pictorial representation of animals and diamond figures may pose less of a stress, or use different systems, than those used for the comparison of Time represented as words. Both of these tasks require an analysis of size, a physical attribute, which is quite different from the analysis of time.

This finding lends support to the hypothesis that age-related decline in inhibitory functioning is related to the amount of processing required by the task, with older individuals showing larger NPEs as a function of processing levels. However, the comparative nature of the Animal task, as with the Diamond and Time tasks, may require the use of an episodic retrieval mechanism in order to carry out the task. If so, one could extend the argument presented in Experiment 2. When an episodic retrieval mechanism is used, the amount of processing needed to complete the task will dictate the amount of interference the individual will have to deal with after the tag has been retrieved. And, at deeper levels of processing, this interference will affect older individuals more than younger ones. In the present experiment, the closer on the continuum of size the two animals are, the more interference will occur after the retrieval of the 'do not respond' tag, thus creating a greater NPE for older individuals but not for young ones.

General Discussion

The objectives of the present thesis were to address some of the un-reconciled issues concerning the age-related inhibitory deficit hypothesis. Specifically, there were four major goals. The first goal was to explore some of the possible reasons why in some cases, older adults showed a NPE and in other cases they did not show this effect. The second goal was to force processing at different levels in order to see how this manipulation may affect outcome on a normal aging population as compared to younger adults, as well as within a population of older individuals who were believed to have deficits related to inhibitory functioning. The third goal was to examine the relationship between interference and inhibitory functioning. And, the fourth goal was to examine the relationship among other indices of inhibitory deficits, specifically, those related to the frontal lobe.

The results of the three Experiments strongly support the hypothesis that older adults experience some form of deficit as measured by NPEs, but do so differentially depending on the demands of the task. Further, these results support the idea that greater processing demands affect the amount of the NPE seen in both the young and old but these variations in processing demands appear to affect the old to a greater extent than the young. The negative priming paradigm was seen as the 'gold standard' for assessing inhibitory attentional processes. Earlier failures to find NPEs in the old were used as evidence to support the age-related inhibitory deficit hypothesis, whereas findings of equal NPEs were used, by some, as evidence for a dual mechanism model (episodic and inhibitory, e.g, May et al. 1995) and by others, as a refutation of the inhibitory deficit hypothesis (Sullivan & Faust, 1993; Kramer et al., 1994; Schooler et al., 1997; Kieley & Hartley, 1997; Gamboz, et al., 2000). One of the major differences between the current results and those of the past is that older individuals produced a larger NPE than the young on the Time task, which required semantic analysis and thus made the greatest processing demands. This same negative priming task was also able to differentiate among OTV groups, with the group believed to have the greatest decline in inhibitory and executive control processes showing the largest NPE. This latter finding is in contrast to the findings with the tasks that required attention to the visual features of the stimuli (Letter, Diamond). These tasks were not able to differentiate among the OTV groups. Another major finding was that older individuals were more affected than younger ones by the closeness of items on a continuum of size, which was believed to pose greater task demands than items which were further apart. In contrast, the same older adults showed an equal increase in the NPE, relative to young adults, in the Same size condition, which was also believed to pose greater processing demands than the real size condition. One more major finding is that the NPEs from the three tasks did not relate to one another, suggesting a lack of individual consistency with respect to the degree of susceptibility to different task manipulations and, perhaps, to the declines of different inhibitory mechanisms. Finally, similar to past results was the lack of consistency with respect to the association between interference and the NPE.

While some of these finding could be interpreted using an episodic retrieval explanation versus an inhibitory one, it is the view here that, in some cases, if not all, there is likely a mix of inhibition and episodic retrieval occurring. Tipper (2001) has argued, that despite the fact that episodic retrieval may account for part of the NPE, an inhibitory mechanism must also be present. This mechanism, he argues, is a reactive one and as such will react to a stronger or lesser degree depending on the amount of activation caused by the distractor. The current battle between different explanations for the NPE is not a useful one. Some form of retrieval of previously disregarded information is a requirement of the task. In some cases, there are likely other mechanisms at work which have not yet been discovered. It may prove far more useful to merge these views together, as suggested by Tipper, in order to gain a better understanding of potential declines, or lack thereof, as one ages. If these reasonable and well thought out explanations are integrated, then theories of declines in aging which incorporate an inhibitory mechanism do not by default need to be dismissed because of the episodic retrieval aspect of some, or all, of the results. Indeed, some findings from the present study support the age-related inhibitory decline hypothesis and help clarify the controversies due to disparate results by different studies.

There is at least one possible explanation for the results found here and those of past studies that incorporates both the episodic retrieval and the inhibition account of negative priming. Perhaps we are still dealing with the result of a decline in inhibitory functioning but, because episodic retrieval likely also comes into play, we see different effects on older adults depending on task demands. At deeper levels of processing, an inhibitory mechanism may be needed to get past the conflict between the 'do not respond' tag placed at the prime and the current need to respond to that stimulus at the probe. Kieley and Hartley (1997) suggested the possibility of a second inhibitory mechanism responsible for inhibition at the probe. An inhibitory mechanism may be needed to 'inhibit' the old 'do not respond' tag in order for the new 'respond' tag to take its place. If older individuals are not as efficient as the young in the ability to inhibit, then they may have more difficulty getting over this conflict.

Another possibility is that interference is happening in two places (prime and probe) and is treated differently, depending on the point in time, by one or more inhibitory mechanisms. If interference is intruding in two places, then inhibition is also likely working in these same places (prime and probe). The usual way of measuring interference is to add a distractor to the display, with the difference between reaction time for this condition and reaction time to respond to a single target representing interference. This measure tells us how much the individual is affected by distraction at the level of the prime within the negative priming condition and during both the prime and probe within the control condition. However, the negative priming paradigm has been set up to measure the amount of inhibition taking place on the prime as seen by the increase in time to retrieve a previously inhibited item at the probe. If there is interference at the level of the probe, then this is a different type of interference from that taking place on the prime. It is no longer external stimuli which constitute the interference, but rather, it is the internal representation of the previous tag which is interfering and in need of suppression. In the first case, the system must deal with keeping the distractor out of working memory in order to correctly tag both items of the pair and respond to the target. In the second case, an inhibitory mechanism, perhaps different from the one used in the first case, must deal with internally generated information which has been previously processed to varying degrees depending on the task. Because older individuals appear to be more affected by interference than younger ones, they may have an especially big load to deal with during a deep processing task. It may be that the interference occurring after the tagged item has been retrieved is responsible for the NPE. This type of interference could explain why there have been inconsistent results, both in past studies and in the present one, with respect to the association between interference and negative priming. It may also explain why interference, as measured by the Stroop test, positively relates to negative priming. The Stroop test, depending on the variation used, generally calls upon already established memory for the association between color and a word representing color. The interference caused by the discrepancy between the word and the color of the ink can be likened to the interference taking place at the level of the probe.

Initially, the analysis of 'closeness' on the continuum of Time and of Diamond size in Experiment 2, and the adjacent versus non–adjacent conditions, based on the continuum of animal size in Experiment 3, were both conceptualized as assessing the impact of varying depths of processing on the NPE. However, after completion of the second and third experiments, it was speculated that it may not be depth of processing that is being manipulated, but rather, the amount of thought needed to judge two items close on the continuum. Depth of processing, originally defined by Craik and Lockhart (1972), relates to the level at which stimuli are processed. For example, letter stimuli can be said to be processed at a far shallower depth than are semantic stimuli. If one is judging the size difference between two animals in order to say that one is bigger than the other, then processing is completed at a specific 'level' (deeper than letters and perhaps shallower than the abstract nature of time). The judgment made between two animals that are adjacent on the continuum of size may take more thought than a judgment made between two animals that are non-adjacent but the judgments are not being made at different levels of processing (i.e., one is not more semantic than the other). With this idea in mind, it may be that this kind of manipulation constitutes varying the amount of interference and not the levels of processing. If this is the case, then the results found in this study, based on the analysis of closeness on a continuum, may mean that older individuals are more affected than younger ones by an increase in interference within the negative priming task itself. It may be that the increase in amount of thought needed to judge items which are close on a continuum floods the available space in working memory in the old whereas, because the young have more available space, they are less affected by the increase in amount of thought needed to respond. The strong association between probe reaction time and closeness on a continuum for probe items, seen in Experiment 2, suggest that this increase in amount of thought is taking place at the level of the probe. This association could be seen as support for the above argument that the NPE is due to an inhibitory mechanism having to deal with the interference taking place after the retrieval of previously discarded information.

As has been previously discussed, it is possible that the NPE, in all cases, is in part, the result of episodic retrieval. The notion of a 'weak' tag being used for shallow processing tasks, a 'strong' tag for intermediate processing tasks, and a 'super' tag for deep processing tasks can help to explain the NPE shown by both the young and the old.

The NPE itself increases in magnitude as a function of depth of processing for both age groups. A 'weak' tag placed by the young may explain the small NPEs found in the young using tasks, such as the Letter task, which are based on letter identification and color. A good 'young' memory may be affected by even a very 'weak' tag whereas a poor 'old' memory may not be affected by this strength of tag. The NPE, seen and not seen in older adults, as compared to the young, may be due to the combination of a compromised memory and an increase in susceptibility to interference, which in turn is due to deficient inhibitory functioning.

The High OTV group in Experiment 2, showed a larger NPE than the lower OTV groups in the Time task. This group has been found to be particularly susceptible to interference and do more poorly on switching tasks and set breaking, all of which are believed to be related to inhibitory and executive control processes (Arbuckle & Gold, 1993; Pushkar Gold & Arbuckle, 1995). It has been already argued that the Time task is generating the greatest amount of interference as compared to the other negative priming tasks used in the present study. It maybe because of this interference, that the High OTV group showed a larger NPE than the other groups. A high level of interference is likely to tax an already deficient inhibitory system responsible for reducing internally generated conflict. This conflict may be taking place in mechanisms related to higher cortical functions, such as those associated with the frontal lobes, as opposed to perceptually based systems.

Levels of processing per se seems to have more of an effect on older individuals than on younger ones but it does not appear to be the whole story. Based on the arguments of Posner and Peterson (1990), there are several possible combinations of pathways to respective brain systems depending on demands of the stimuli and/or task requirements. A fairly clear pattern can be seen when negative priming tasks are separated based on the areas of the brain and different systems that might be being used for selection. The posterior related systems are those believed to be concerned with physical attributes such as color. The majority of studies where target selection was based solely on color and a rather superficial analyses of the stimuli were those where no NPE was found for older adults (overlapping letters printed in different colors: McDowd & Oseas-Kreger, 1991; Hasher, et al., 1991; Stolzfus, et al., 1993; Current Experiment 1 and 2; separate words in different colors; Kane, et al., 1994; although see Earles et al., 1997 and Gamboz, at al., 2000 for equal NPEs using similar stimuli). Studies based solely on location have found equal NPEs for the old and young, (Connelly & Hasher, 1993; McDowd & Filion, 1995) suggesting the possibility of another mechanism within the posterior system or the use of a combination of anterior and posterior systems.

The anterior-related systems are believed to be those concerned with decision-making and semantic analyses. Studies using stimuli with a semantic load have all found equal NPEs for the young and old (Stroop material; Kieley & Hartley, 1997; semantic, conceptual conditions; Schooler et al., 1997) And, the present study found equal and greater NPEs for the old as compared to the young, using decision-making/semantic tasks (current study, comparative judgments of size of Diamonds and Animals, comparison of duration of Time). Combinations of the above have included a task using separate pictures but based on location where no NPE was found for the old (Tipper, 1991); a mixture of location and identity finding equal NPEs for old and young (Kramer et al., 1994); a mix of color and superimposed pictures which found equal NPEs (Sullivan &

Faust, 1993); and a mix of color and difficulty which also found equal NPEs (Kane et al., 1997). Although this a very simplistic look at how stimuli and tasks may be related to the brain, the color component, the semantic component, location and perhaps mixtures of all of these are likely requiring separate systems and different mechanisms or combinations of different systems and mechanisms from both the posterior and anterior regions. The areas of research addressing attentional processes using the negative priming paradigm and those concerned with neuropsychological functioning, for the most part, are from separate literatures. There is a missing link with respect to a neuroscience approach which looks at structural declines in the frontal lobes and approaches concerned with the behavioral manifestations of declines in inhibitory functioning. The data collected here are not sufficient to make this link, thus, these findings remain only suggestive. There is a need for a different level of measurement in future studies which could include for example, brain scans.

An example of a possible interaction of mechanisms could be the explanation for the results found for the Diamond task in Experiment 1 and 2. The Diamond task yielded equal NPEs for the young and old, as well as for each OTV group. The task involves both the processing and judging of the size of the target and distractor, the target's location, and the perception of physical attributes. It may be that this combination of requirements taxed both the posterior and anterior related systems. Perhaps this combination results in a tradeoff among the different inhibitory mechanisms resulting in a leveling of the behavioral effects.

It is worthy of note that variations in the Stroop paradigm, like the different NPEs in the current study, have also yield individual inconsistencies. Shilling et al. (2002)

found that different variations on the Stroop task all resulted in greater effects for older individuals, as compared to younger ones, but the different tasks did not relate to one another. It may be that variations on the Stroop task, as with different NP tasks, tap different parts of the brain and/or pose different degrees of interference, which do not necessarily relate to the same declines in each individual.

The distinction, based on results from previous studies, made between an 'identity' based inhibitory mechanism and one based on 'location' is far too simplistic. We are already well aware of the fact that the brain is extremely complex and has functions which are intricately intertwined. To assume that there are only one or two inhibitory mechanisms is not practical, nor wise. The negative priming paradigm can be seen as an albatross which causes headaches for the hypothesis of age-related declines in inhibition, or, it can be viewed as a very strong paradigm which has the sensitivity, and therefore the potential, to aid in distinguishing among several inhibitory mechanisms dealing with different kinds of interference and episodic retrieval. Future studies should focus on the negative priming stimuli and the requirements made by specific tasks and how these may relate to already established measures, or disorders that are known to relate to different systems of the brain. A systematic look at how different negative priming tasks relate to age and their association with other measures would help illuminate the parameters surrounding the current age-related inhibitory deficit hypothesis. Future studies should also focus on trying to establish when interference is taking place, with respect to the sequence of events, and how one might best measure the type of interference occurring at each point in the sequence. It makes sense that the amount of interference that older adults are dealing with is a function of the extent of decline in inhibitory functioning. Pinpointing where and how interference is occurring, in relation to the NPE produced, may better establish this link more consistently than has been seen in previous studies.

One of the implications of this research is that a better understanding of the normal aging process will help to give us insight into the specific problems which result from various age-related disorders. If we know how the normal aging processes affects cognitive processes then we will be better able to pick up on more subtle manifestations of 'non-normal' aging and perhaps be able to stop the progression of some disorders earlier than we are currently. As well, knowledge of what cognitive declines are associated with aging and what cognitive abilities remain intact may help us set up resources that are better suited to the aging population. For example, knowing that older individuals have more difficulty than younger individuals with selective attention, and that this difficulty is due to poor inhibitory functioning, will help us to improve upon the design of signs and information pamphlets by reducing potential interference.

References

Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition, and verbosity. Journal of Gerontology: Psychological Sciences, 48, P225-P232.

Arbuckle, T.Y., LeClair, M. & Pushkar, D. (2000). Effect of off-target verbosity on communication efficiency in a referential communication task. Psychology and Aging, 15, 65-77.

Arnsten, A.F.T., Cai, J.X., Murphy, B.L., & Goldman-Rakic, P.S. (1994). Dopamine D1 Receptor mechanisms in the cognitive functioning of young adult and aged monkeys. Psychopharmacology, 116, 143-151.

Beech, A., & Claridge, G. (1987). Individual differences in negative priming: Relations with schizotypal personality traits. British Journal of Psychology, 28, 109-116.

Benton, A., & Hamsher, K. (1976).Multilingual Aphasia Exam. Iowa City: University of Iowa.

Cerella, J. (1985). Information processing rates in the elderly. Psychological Bulletin, 98, 67-83.

Clark, H.H. (1973). The language-as fixed effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 12, 335-359.

Cohen, J.D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. Behavior Research Methods, Instruments and Computers, 25, 257- 271.

Connelly, S. L., & Hasher, L. (1993). Aging and the inhibition of spatial location. Journal of Experimental Psychology: Human Perception and Performance, 19, 1238-1250.

Connelly, S. L., Hasher, L., Zacks, R. T. (1991). Age and reading: The impact of distraction. Psychology and Aging, 6, 533-541.

Craik, F.I., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F.I. Craik & S. Trehub (Eds.), Aging and Cognitive Processes (pp. 191-211). New York: Plenum.

Craik, F.I. & Lockhart, R.S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671–684.

Craik, F.I., & Rabinowitz, J.C. (1984). Age differences in the acquisition and use of verbal information: A tutorial review. In H. Bouma & D.G. Bouwhuis (Eds.), Attention and Performance X: Control of Language Processes (pp. 471-499). London: Erlbaum.

Craik, F.I. & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology, 104, 268–294.

Dalrymple-Alford, E. C. & Budayr, B. (1966). Examination of some aspects of the Stroop Color-Word Test. Perceptual Motor Skills, 23, 1211-1214.

Dempster, F.N. (1992). The rise and fall of the inhibitory mechanism: towards a unified theory of cognitive development and aging. Developmental Review, 12, 45-75.

Desimone, R., Albright, T.D., Gross, C.G., & Bruce, C. (1984). Stimulus selective properties of inferior temporal neurons in the macaque. Journal of Neuroscience, 4, 2051-2062.

Driver, J., & Tipper, S. P. (1989). On the nonselectivity of "selective" seeing: Contrasts between interference and priming in selective attention. Journal of Experimental Psychology: Human Perception and Performance, 15, 304-314.

Earles, J.L., Conner, L.T., Frieske, D., Park, D.C., Smith, A.D., & Zwahr, M. (1997). Age differences in inhibition: Possible causes and consequences. Aging, Neuropsychology, and Cognition, 4, 45-57.

Fabi, K. (2000). Negative Priming Effect as a function of age and level of processing. Unpublished manuscript, Concordia University at Montreal.

Gamboz, N., Russo, R. & Fox, E. (2000). Target selection difficulty, negative priming, and aging. Psychology and Aging, 15, 542-550.

Georgescu, M. (2001). Age differences in the impact of the level of processing on the Negative priming effect. Unpublished manuscript, Concordia University at Montreal.

Greenwald, A. G. (1972). Evidence of both perceptual filtering and response suppression for rejected messages in selective attention. Journal of Experimental Psychology, 94, 58-67.

Gold, D. Andres, D., Arbuckle, T., & Schwartzman, A. (1988). Measurement and correlates of verbosity in elderly people. Journal of Gerontology: Psychological Sciences, 43, P27-P33.

Hartley, A.A. (1993). Evidence for the selective preservation of spatial attention in old age. Psychology and Aging, 8(3), 371-379.

Hasher, L., Stoltsfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 163-169.

Hasher, L. & Zacks, R. (1984). Automatic processing of fundamental information: The case of frequency of occurrence. American Psychologist, 39, 1372-1388.

Hasher, L., & Zacks, R. (1988). Working memory, comprehension, and aging: A review and a new view. In G. Bower (Ed.), The psychology of learning and motivation (pp. 193-325). New York: Academic Press.

Haug, H., & Eggers, R. (1991).Morphometry of the human cortex cerebri and cortex Striatum during aging. Neurobiology of Aging, 12, 336-338.

Jacoby, L. L., Craik, F. I. M., & Begg, I. (1979). Effects of decision difficulty on recognition and recall. Journal of Verbal Learning and Verbal Behavior, 18, 585-600.

Kane, M. J., Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Connelly, S. L. (1994). Inhibitory attentional mechanisms and aging. Psychology and Aging, 9, 103-112.

Kane, M. J., May, C. P., Hasher, L., Rahhal, T. & Stoltzfus, E. R. (1997). Dual mechanisms of negative priming. Journal of Experimental Psychology: Human Perception and Performance, 23, 632-650.

Keele, S. W., & Neill, W. T. (1978). Mechanisms of attention. In E. C. Carterette & M. P. Friedman (Eds.), Handbook of perception (Vol. 9, pp. 3-47). New York: Academic Press.

Kiely, J. M. & Hartley, A. A. (1997). Age-related equivalence of identity suppression in the Stroop Color-Word Task. Psychology and Aging, 12, 22-29.

Kramer, A. F., Humphrey, D. G., Larish, J. F., Logan, G. D., & Strayer, D. L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. Psychology and Aging, 9, 491-512.

Lezak, M.D. (1995). Neuropsychological Assessment (3rd ed.) New York: Oxford.

Logan, C. D. (1988). Toward an instance theory of automatization. Psychological Review, 95, 492-527.

Logan, C.D. (1990). Repetition priming and automaticity: Common underlying mechanisms? Cognitive Psychology, 22, 1-35.

Logan, C.D., & Cowan, W. (1984). On the ability to inhibit thought and action: A theory of an act of control. Psychological Review, 91, 295-327.

MacDonald, P.A., Joordens, S., & Seergobin, K.N. (1999). Negative priming effects that are bigger than a breadbox: Attention to distractors does not eliminate negative priming, it enhances it. Memory and Cognition, 27, 197-207.

May, C. P., Kane, M. J. & Hasher, L. (1995). Determinants of negative priming. Psychological Bulletin, 118, 35-54.

McDowd, J. M., & Filion, D. L. (1995). Aging and negative priming in a location suppression task: The long and the short of it. Psychology and Aging, 10, 34-47.

McDowd, J. M., & Oseas-Kreger, D. M. (1991). Aging, inhibitory processes, and negative priming. Journal of Gerontology: Psychological Sciences, 46, P340-P345.

Milliken, B., Joordens, S., Merikle, P.A., & Seiffert, A.E. (1998).Selective attention: A reevaluation of the implications of negative priming. Psychology Review, 105, 203-229.

Neill, W. T. (1977). Inhibitory and facilitatory processes in selective attention. Journal of Experimental Psychology: Human Perception and Performance, 3, 444-450.

Neill, W. T, & Valdes, L. A. (1992). Persistence in negative priming: Steady state or decay? Journal of Experimental Psychology: Learning, Memory and Cognition, 18, 565-576.

Neill, W.T., Valdes, L.A., Terry, K.M., & Gorfein, D.S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 993-1000.

Neill, W. T., & Westberry, R. L. (1987). Selective attention and the suppression of cognitive noise. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 327-334.

Pesta, B.J., & Sanders, R.E. (2000). Aging and negative priming: is ignored information inhibited or remembered? Experimental Aging Research, 26, 37-56.

Posner, M.I. (1992). Attention as a cognitive and neural system. Current Directions in Psychological Science, 1, 11-15.

Posner, M. I., & Cohen, Y. A. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), Attention and performance (Vol. 10, pp. 531-556). Hillsdale, NJ: Erlbaum.

Posner, M.I., & Peterson, S. (1990). The attention system of the human brain. Annual review of Neuroscience, 13, 24-42.

Pushkar Gold, D. & Arbuckle, T.Y. (1995). A longitudinal study of off-target verbosity. Journal of Gerontology Psychological Science, 50B, P307-P315.

Reitan, R., & Davison, L. (1974). Clinical Neuropsychology: Current State and Applications. Washington, DC: Winston.

Salthouse, T. A. (1982). Adult cognition: An experimental psychology of human aging. New York: Springer-Verlag.

Scheibel,M.E., & Scheibel, A.B. (1975).Structural changes in the aging brain. In H. Brody, D. Harmon, & J.M. Ordy (Eds.), Aging. (Vol. 1, pp. 11-37). New York: Raven Press.

Schooler. C., Neumann. E., Caplan. L.J., & Roberts, B.R. (1997). Continued inhibitory capacity throughout adulthood: Conceptual negative priming in younger and older adults. Psychology and Aging, 12, 667-674.

Shilling, V.M., Chetwynd. A., & Rabbitt, P.M.A. (2002). Individual inconsistency across measures of inhibition: An investigation of the construct validity of inhibition in older adults. Neuropsychologia, 40, 605-619.

Stoltzfus, E. R., Hasher, L., Zacks, R. T., Ulivi, M. S., & Goldstein, D. (1993). Investigations of inhibition and interference in younger and older adults. Journal of Gerontology: Psychological Sciences, 48, P179-P188.

Stroop, J.R. (1935). Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 18, 643-662.

Sullivan, M. P., & Faust, M. E. (1993). Evidence for identity inhibition during selective attention in old adults. Psychology and Aging, 8, 589-598.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. The Quarterly Journal of Experimental Psychology, 37A, 571-590.

Tipper, S. P. (1991). Less attentional selectivity as a result of declining inhibition in older adults. Bulletin of the Psychonomic Society, 29, 45-47.

Tipper, S.P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. The Quarterly Journal of Experimental Psychology, 54A, 321-343.

Tipper, S. P., Bourque, T. A., Anderson, S. H., & Brehaut, J. C. (1989). Mechanisms of attention: A developmental study. Journal of Experimental Child Psychology, 48, 353-378.

Tipper, S. P., & Cranston, M. (1985). Selective attention and priming: Inhibitory and facilitory effects of ignored primes. The Quarterly Journal of Experimental Psychology, 37A, 591-611.

Tipper, S. P., & McLaren, J. (1990). Evidence for efficient visual selectivity in children. In J. T. Enns (Ed.), The development of Attention: Research and Theory (pp. 197-210). Amsterdam: North-Holland.

Tipper, S. P., Weaver, B., Cameron, S., Brehaut, J. C., & Bastedo, J. (1991). Inhibitory mechanisms of attention in identification and localization tasks: Time course and disruption. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 681-692.

Trenerry, M.R., Crosson, B., DeBoe, J., & Leber, W.R. (1989). The Stroop Neuropsychological Screening Test. Odessa, FL: Psychological Assessment Resources.

Ungerleider, L.G., & Mishkin, M. (1982). Two cortical visual systems. In D.J. Ingle, M.A. Goodale, & R.J.W. Mansfield (Eds.), Analysis of Visual Behaviour (pp.

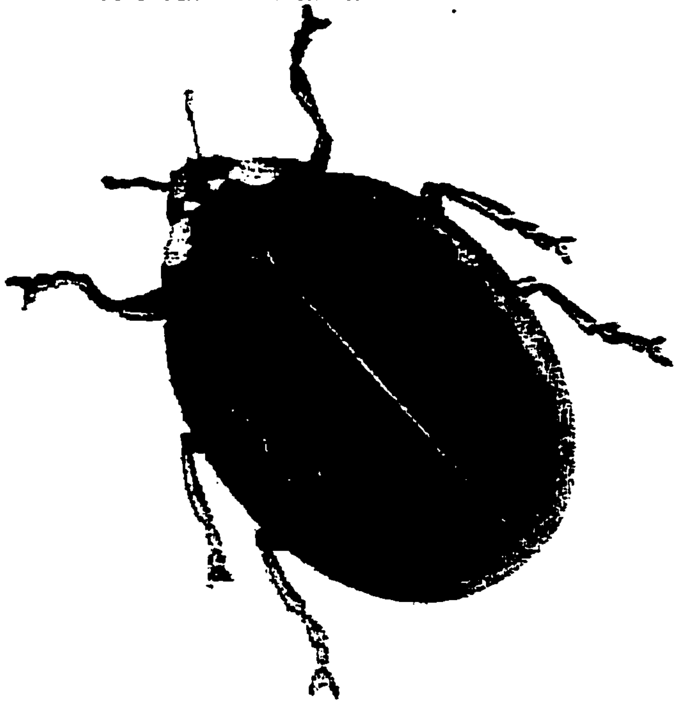
549-586). Cambridge, MA: MIT Press.

Verhaeghen, P, & Meersman, L.D. (1998). Aging and the negative priming effect: A meta-analysis. Psychology and Aging, 13, 435-444.

West, R.L. (1996). An application of prefrontal cortex function theory to cognitive aging. Psychological Bulletin, 120, 272-292.

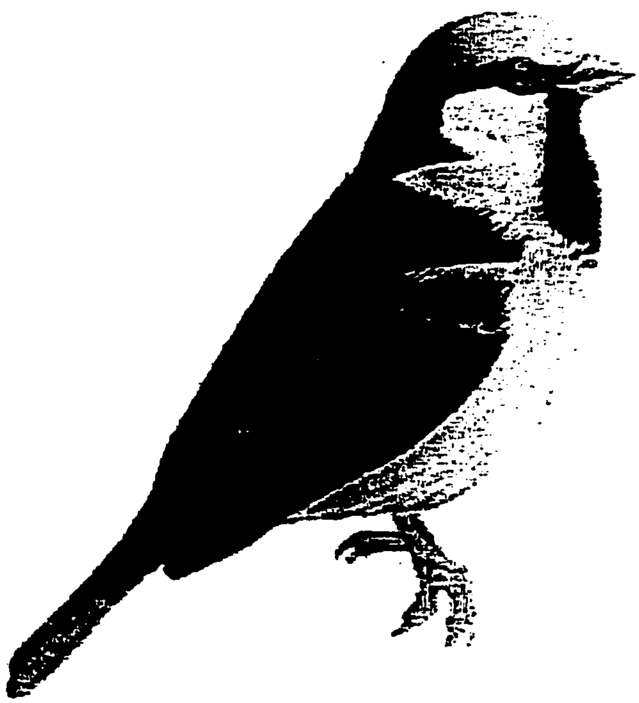
Appendix A

A-1. Animal Stimuli



Ladybug

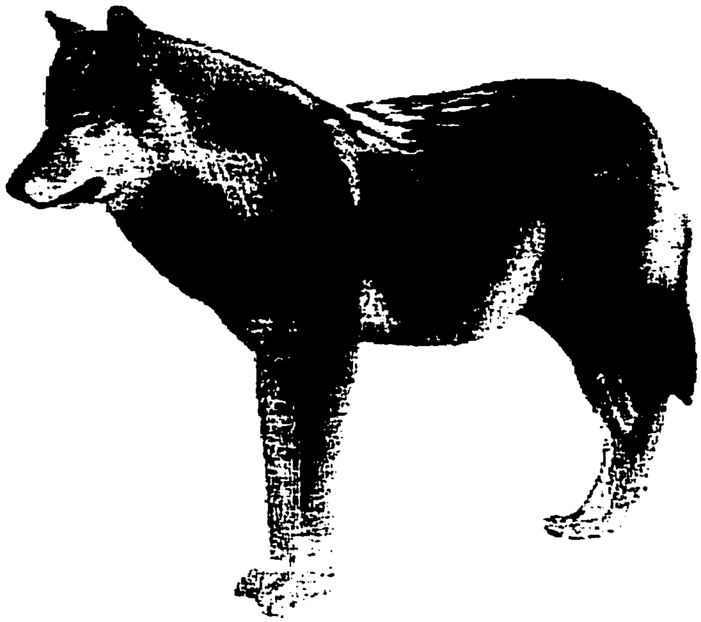
Butterfly



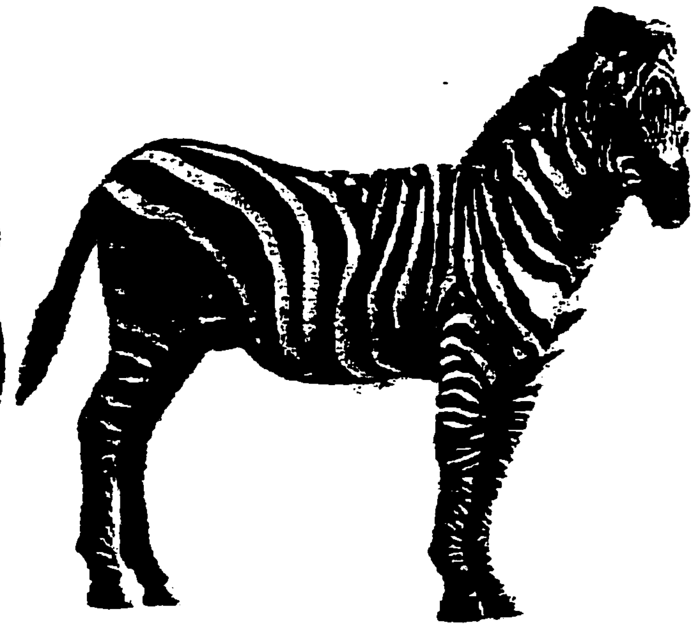
Bird

Cat

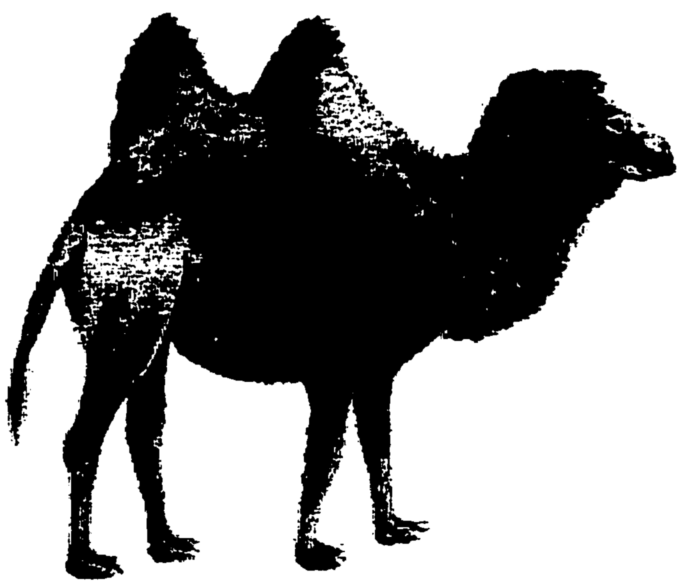
A-1. Animal Stimuli (cont')



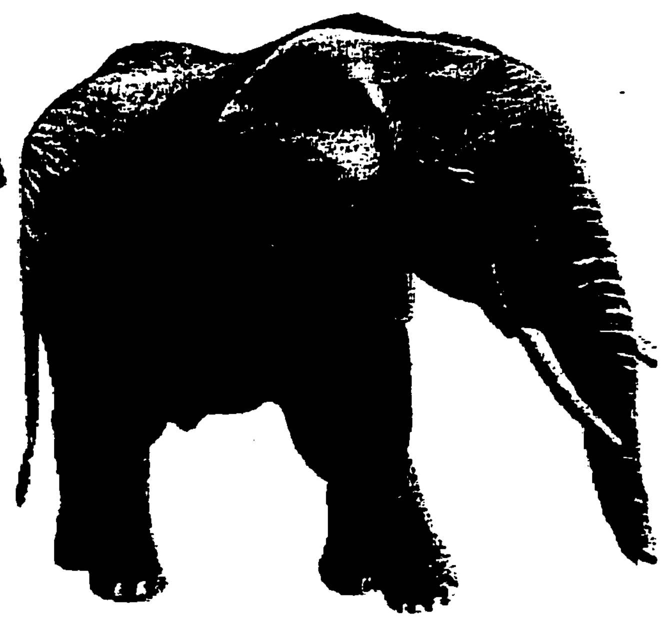
Wolf



Zebra

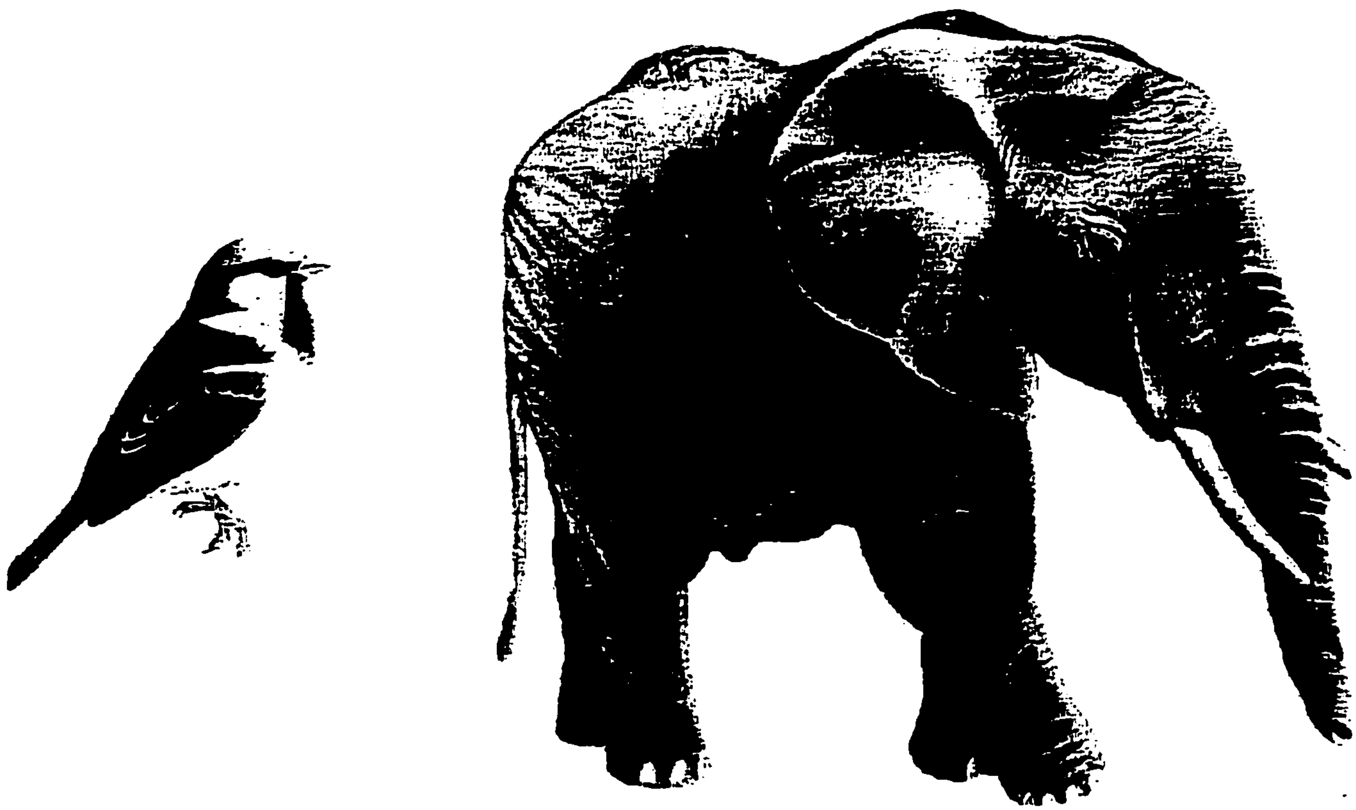


Camel

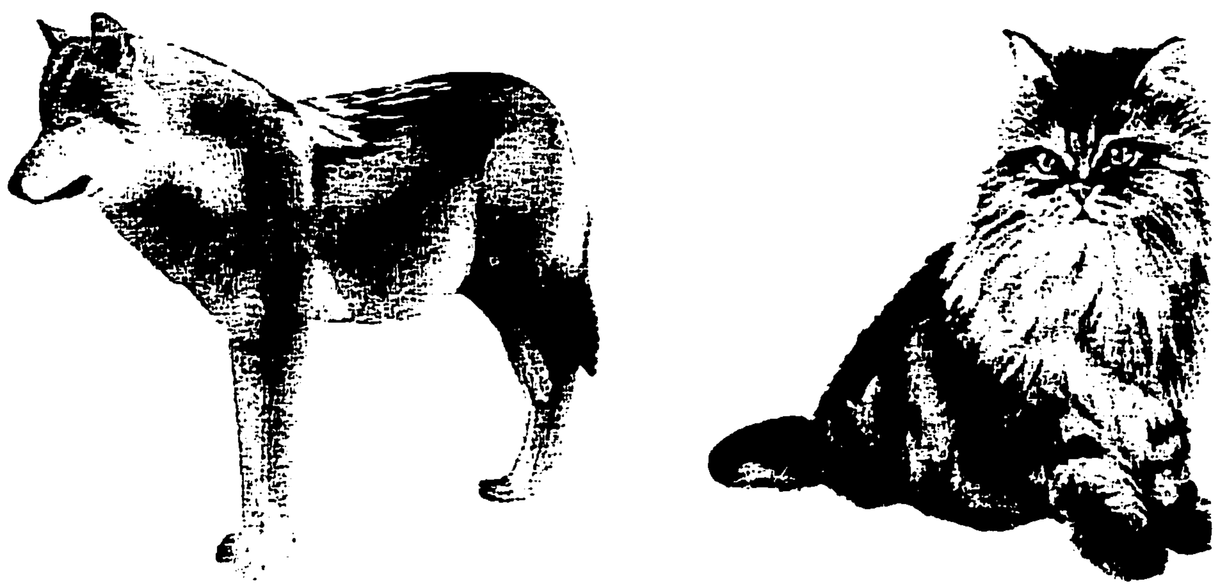


Elephant

A-2. Example of Real size pair stimuli



A-3. Example of Same size pair stimuli



A-4. Lists of the animal pairings

List 1			List 2			List 3		
Prime	Probe	Trial	Prime	Probe	Trial	Prime	Probe	Trial
8-4	2-7	F	1-6	3-8	F	8-3	2-6	F
1-5	6-2	F	5-1	7-2	F	1-8	3-7	F
3-8	1-7	F	4-8	7-1	F	6-1	7-2	F
4-2	5-3	C	3-4	5-2	C	5-3	1-3	NP
6-8	6-4	NP	8-7	6-7	NP	2-4	5-7	C
2-5	8-7	C	1-2	4-3	C	8-6	6-3	NP
6-3	2-3	NP	7-6	6-3	NP	4-5	8-7	C
7-4	4-1	NP	2-5	4-7	C	3-1	5-4	C
6-5	3-4	C	8-6	5-3	C	7-8	6-7	NP
7-8	7-6	NP	2-4	2-1	NP	2-1	6-8	C
1-4	2-5	C	3-5	1-3	NP	3-4	3-2	NP
4-3	1-3	NP	5-7	6-8	C	5-1	6-4	C
6-7	5-6	NP	7-4	1-4	NP	2-3	5-6	C
2-1	8-6	C	6-2	7-8	C	8-4	4-2	NP
4-5	3-2	C	6-4	4-2	NP	6-5	3-5	NP
7-5	5-4	NP	5-8	4-5	NP	4-7	3-2	C
1-3	5-7	C	3-1	5-6	C	4-6	4-3	NP
4-6	2-4	NP	3-7	3-2	NP	7-5	1-4	C
5-3	1-2	C	4-1	6-5	C	2-5	1-2	NP

Legend

1 = ladybug
2 = butterfly
3 = bird
4 = cat
5 = wolf
6 = zebra
7 = camel
8 = elephant