Die Bedeutsamkeit von inhibitorischen Aufmerksamkeitsmechanismen für das Auftreten von Altersunterschieden beim Lesen mit Distraktoren

Inaugural-Dissertation

zur

Erlangung des Doktorgrades

der Mathematisch-Naturwissenschaftlichen Fakultät

der Heinrich-Heine-Universität Düsseldorf

vorgelegt von

Iris Mund

geboren in Düsseldorf

Oktober 2010

Aus dem Institut für Experimentelle Psychologie

Der Heinrich-Heine-Universität Düsseldorf

Gedruckt mit Genehmigung

Der Mathematisch-Naturwissenschaftlichen Fakultät der

Heinrich-Heine-Universität Düsseldorf

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Tag der mündlichen Prüfung:	06. 12. 2010

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Zusammenfassung

Kernthema vorliegender Arbeit ist die systematische Analyse alterskorrelierter kognitiver Veränderungen. Im Zentrum der Untersuchungen steht dabei die Frage, ob Altersunterschiede beim Lesen mit Distraktoren einen Beleg für ein altersbezogenes Defizit der inhibitorischen Aufmerksamkeitskontrolle darstellen. Die übliche Aufgabe der Probanden in diesem Paradigma besteht darin, kurze Textpassagen laut vorzulesen, in welche in den Experimentalbedingungen Distraktorwörter eingestreut sind. In der Regel findet man, dass die Leseleistung älterer Erwachsener durch die eingestreuten Distraktorwörter stärker beeinträchtigt ist als die jüngerer Erwachsener. Dieser Befund dient als wichtige empirische Stütze für die Annahme eines altersbedingten Defizits in der inhibitorischen Aufmerksamkeitskontrolle und wird immer wieder in Überblicksartikeln zitiert. Allerdings sprechen die Altersunterschiede beim Lesen mit Distraktoren nicht eindeutig für ein Problem der Interferenzkontrolle im höheren Lebensalter, denn es existieren Alternativerklärungen und Inkonsistenzen hinsichtlich der veröffentlichten Befunde. Durch methodische Verbesserungen sollte in vorliegender Arbeit die Interpretation des Befundmusters disambiguiert werden. Hierbei zeigte sich, dass die Altersunterschiede beim Lesen mit Distraktoren zwar teilweise, aber nicht ausschließlich durch altersbedingte Veränderungen in der Sehschärfe erklärt werden können. Dieser Sachverhalt legt den Schluss nahe, dass tatsächlich altersbezogene Defizite in höheren kognitiven Prozessen - wie eine Reduktion der inhibitorischen Aufmerksamkeitskontrolle - ursächlich für die Altersunterschiede sind. Allerdings zeigen die vorliegenden Daten auch, dass das Auftreten von Altersunterschieden in der Beeinträchtigung der Leseleistung von der konkreten Umsetzung des experimentellen Paradigmas abhängt. Diese Tatsache ist konsistent mit der Auffassung, dass altersbedingte Defizite in bestimmten Inhibitionsfunktionen existieren, ältere Menschen jedoch nicht generell eine erhöhte Interferenzanfälligkeit aufweisen. Die vorliegende Arbeit liefert somit Evidenz für die Annahme, dass die Inhibitionsdefizittheorie als globale Theorie des kognitiven Alterns kritisch betrachtet werden muss und stattdessen spezifischere Theorien zur Interferenzanfälligkeit im höheren Lebensalter nötig sind, um das komplexe Muster altersbedingter Veränderungen in inhibitorischen Aufmerksamkeitsmechanismen auf Modellebene abzubilden.

Abstract

The present research focuses on the systematic analysis of age-related changes in cognitive functioning. The investigations address the issue whether age differences in the reading-with-distraction task provide evidence for an age-related deficit in inhibitory attentional control. In the original version of the reading-with-distraction task, participants are required to read aloud short texts in which distractor words are interspersed in the experimental conditions. Older adults' reading performance is usually more impaired by the presence of distractor words than younger adults' reading performance. This finding provides empirical support for an age-related deficit in inhibitory attentional control and is frequently cited in review articles. Nevertheless, age differences in the reading-with-distraction task cannot be unambiguously attributed to age-related problems with interference control because there are alternative explanations and inconsistencies regarding the pattern of published results. The aim of the present work was to disambiguate the interpretation of the data pattern by applying methodological improvements. The present results showed that the age differences in the reading-with-distraction task are to some degree, but not exclusively due to age-related perceptual deficits. This circumstance leads to the conclusion that deficits in higher cognitive processes such as a reduction of inhibitory attentional control are in fact causing the observed age differences. However, the present data also demonstrated that the occurrence of age differences in the impairment of reading performance depends on the specific implementation of the experimental paradigm. This fact is consistent with the assumption that there are age-related deficits in certain inhibitory functions, but that older people do not generally show enhanced susceptibility to interference. The present work thus provides evidence for the assumption that inhibition deficit theory has to be viewed critically as a general theory of cognitive aging and that more specific theories of the age-related susceptibility to interference are necessary to depict the complex pattern of age-related changes in inhibitory attentional processes on the modeling level.

Einführung

Die kognitive Entwicklung ist mit Erreichen des Erwachsenenalters keinesfalls vollendet. In der Regel lässt das kognitive Leistungsvermögen mit zunehmendem Lebensalter wieder nach. Diese alterskorrelierte Reduktion der kognitiven Leistungsfähigkeit umfasst verschiedenste kognitive Komponenten wie Gedächtnis, Aufmerksamkeit oder logisches Denken (Light, 2000; McDaniel, Einstein, & Jacoby, 2008). Im Laufe der Jahre wurden zahlreiche Theorien zur Erklärung der alterskorrelierten Leistungsminderung ausgearbeitet. Neben den neurophysiologischen Theorien, die das kognitive Altern auf physiologische Abbauprozesse im zentralen Nervensystem zurückführen (Anstey, Dear, Christensen, & Jorm, 2005), existieren eine Vielzahl kognitionspsychologischer Theorien, welche die mit zunehmendem Alter beobachtbaren Veränderungen der kognitiven Leistungsfähigkeit mit Veränderungen bestimmter Merkmale des kognitiven Systems erklären. Diese Theorien lassen sich in zwei Kategorien einteilen, in spezifische und in globale Theorien des kognitiven Alterns. Spezifische Theorien des kognitiven Alterns basieren auf der Annahme, dass keine einzelne Ursache für die kognitiven Leistungseinbußen verantwortlich ist, sondern Effizienzminderungen verschiedener kognitiver Funktionen. Eine solche kognitive Funktion ist beispielsweise das Erinnerungsvermögen an die Quelle einer Information, welches im höheren Lebensalter nachlässt (Johnson, Hashtroudi, & Lindsay, 1993). Globale Theorien des kognitiven Alterns betonen hingegen, dass kognitives Altern das Ergebnis einer einzelnen Ursache ist, welche die Informationsverarbeitung auf breiter Ebene beeinflusst. Eine solche Ursache kann beispielsweise eine allgemeine Verlangsamung der Geschwindigkeit sein, mit der mentale Operationen ausgeführt werden (Salthouse, 1996). Die Grundannahme dieser *Verarbeitungsgeschwindigkeitstheorie* ist, dass relevante mentale Operationen im höheren Lebensalter nicht mehr in der erforderlichen Schnelligkeit ausgeführt werden können. Deshalb können sie entweder in einem gegebenen Zeitfenster nicht rechtzeitig abgeschlossen werden oder sie sind fehlerhaft, weil auf erarbeitete relevante Zwischenresultate nicht mehr zugegriffen werden kann. Eine weitere sehr populäre globale Theorie des kognitiven Alterns stellt die 1988 von Hasher und Zacks vorgestellte *Inhibitionsdefizittheorie* dar. Auf deren Inhalte soll im Folgenden näher eingegangen werden, da ihre systematische Untersuchung im Fokus der vorliegenden Arbeit steht.

Die Inhibitionsdefizittheorie basiert auf der Annahme, dass die Informationsverarbeitung im Arbeitsgedächtnis nicht nur durch aktivierende Prozesse gesteuert wird, sondern dass darüber hinaus inhibitorische Prozesse nötig sind, um Interferenzen durch aufgabenirrelevante Reize zu unterbinden. In einer späteren Erweiterung der Theorie postulieren Hasher, Zacks und May (1999) drei Funktionen der inhibitorischen Prozesse, die präziser beschreiben, wie die für eine Aufgabe irrelevanten Informationen gefiltert werden. (1) Die Zugangsfunktion (*Access Function*) verhindert, dass durch Umweltreize oder Gedanken automatisch aktivierte, aber irrelevante Informationen in das Arbeitsgedächtnis gelangen. (2) Die Löschfunktion (*Deletion Function*) löscht oder unterdrückt Informationen, die zwar zu einem früheren Zeitpunkt relevant waren, die aber durch eine Veränderung der Aufgabenstellung oder der persönlichen Ziele der Person irrelevant wurden. (3) Die Zurückhaltungsfunktion (*Restraint Function*) bewirkt, dass auch dominante Informationen und geläufige Antwortmöglichkeiten zunächst zurückgestellt werden können, damit auch weniger dominante Informationen auf ihre Relevanz für die jeweilige Aufgabe überprüft werden können. Der Inhibitionsdefizittheorie zufolge arbeiten alle drei Inhibitionsfunktionen mit zunehmendem Alter ineffektiver. Durch dieses zentrale Defizit der inhibitorischen Aufmerksamkeitskontrolle sind bei älteren Erwachsenen mehr irrelevante Elemente im Arbeitsgedächtnis aktiviert als bei jüngeren Erwachsenen. Da die aktivierten irrelevanten Elemente die Verarbeitung sowie die Bereithaltung der relevanten Information beeinträchtigen (Zacks, Hasher, & Li, 2000), resultieren die Leistungseinbußen in einer Reihe von kognitiven Funktionen (Hasher, Lustig, & Zacks, 2007; Lustig, Hasher, & Zacks, 2007).

Viele Befunde und Alltagsphänomene sprechen für altersbedingte Probleme in der inhibitorischen Aufmerksamkeitskontrolle. So berichten viele Senioren von zunehmenden Schwierigkeiten, sich auf eine Tätigkeit zu konzentrieren, während sie von für diese Tätigkeit irrelevanten Umweltreizen umgeben sind. Und auch empirisch konnte gezeigt werden, dass ältere Menschen häufig vom Thema abweichen und irrelevante Informationen in die Verarbeitung von relevanten Informationen mit einbeziehen (McDowd, Oseas-Kreger, & Filion, 1995; Zacks & Hasher, 1994). Darüber hinaus dient insbesondere der Befund, dass ältere Probanden im Vergleich zu jüngeren Erwachsenen einen reduzierten *Negative-Priming*-Effekt zeigen, als Argument für ein altersbedingtes Defizit in der inhibitorischen Aufmerksamkeitskontrolle (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). Überdies wird ein stärker ausgeprägter *Stroop*-Effekt bei älteren Menschen (MacLeod, 1991; Salthouse, Atkinson, & Berish, 2003) häufig im Sinne einer stärkeren Interferenzanfälligkeit bei älteren Erwachsenen interpretiert. Allerdings offenbart eine eingehendere Auseinandersetzung mit der Literatur eine insgesamt widersprüchliche Befundlage. In aktuelleren Publikationen sowie Metaanalysen blieben die Altersunterschiede in der Größe des *Negative-Priming*-Effektes aus (Gamboz, Russo, & Fox, 2002; Grant & Dagenbach, 2000; Kramer & Strayer, 2001). Darüber hinaus konnte eine weitere Metaanalyse zeigen, dass sich der ausgeprägtere *Stroop*-Effekt bei älteren Erwachsenen auch durch eine allgemeine altersbedingte kognitive Verlangsamung und damit mit der Verarbeitungsgeschwindigkeitstheorie erklären lässt (Verhaeghen & De Meersman, 1998). Dementsprechend ließen sich Schlüsselbefunde, die zum Beleg der Inhibitionsdefizittheorie herangezogen wurden, nicht zuverlässig replizieren. Dadurch geriet die Inhibitionsdefizittheorie des kognitiven Alterns stark in die Kritik, und die insgesamt uneinheitliche Befundlage führte zu zahlreichen Kontroversen und zu diametralen Standpunkten innerhalb der Literatur.

Auf der einen Seite wird die Annahme eines altersbedingten Inhibitionsdefizits als falsifiziert betrachtet und jegliche beobachtbaren Altersunterschiede in der kognitiven Leistungsfähigkeit werden auf andere Ursachen als auf altersbezogene Defizite in der inhibitorischen Aufmerksamkeitskontrolle zurückgeführt (Burke, 1997; Burke & Osborne, 2007). Auf der anderen Seite wird der Inhibitionsdefizittheorie weiterhin ein umfangreicher Geltungsbereich attestiert (Hasher et al., 2007; Lustig & Hasher, 2001; Lustig, Hasher, & Tonev, 2001; Zacks et al., 2000). Die inkonsistente Befundlage wird beispielsweise dadurch erklärt, dass die bislang verwendeten Paradigmen unter bestimmten Umständen kein zuverlässiges Maß für inhibitorische Kontrollmechanismen darstellen (Lustig et al., 2007). In der Tat zeigen neuere Befunde, dass der *Negative-Priming*-Effekt weniger auf eine noch vorhandene Restinhibition des zuvor ignorierten Reizes zurückgeht (Tipper, 1985, 2001), sondern vielmehr auf einem Konflikt zwischen der Erinnerung an die geforderte Reaktion in der *Prime*-Episode und der tatsächlich verlangten Reaktion in der *Probe*-Episode beruht (Mayr & Buchner, 2006; Neill, Valdes, Terry, & Gorfein, 1992). Das Argument der unzureichenden Konstruktvalidität von zur Überprüfung der Inhibitionsdefizittheorie verwendeten Paradigmen wie dem *Negative-Priming*-Effekt scheint also nicht eindeutig von der Hand zu weisen zu sein. Dementsprechend gestaltet sich die Einschätzung der Gültigkeit der Inhibitionsdefizittheorie als schwierig.

Doch die bislang diskutierten Befunde sind nicht die einzigen Anhaltspunkte für ein Nachlassen der inhibitorischen Aufmerksamkeitskontrolle mit zunehmendem Lebensalter. Eine der wichtigsten empirischen Stützen für die Annahme eines altersbedingten Inhibitionsdefizits stellt das Befundmuster in einem Paradigma dar, das im Gegensatz zu vorstehend aufgeführten Paradigmen speziell zur Überprüfung der Interferenzanfälligkeit im höheren Lebensalter entwickelt wurde: das *Lesen mit Distraktoren*. In diesem Paradigma lesen ältere und jüngere Erwachsene kurze Texte. In den Experimentalbedingungen werden Distraktorwörter in den zu lesenden Text eingestreut. Diese Distraktoren sind dadurch gekennzeichnet, dass sie einen anderen Schriftstil aufweisen als die zu lesenden Wörter des Zieltextes. Üblicherweise werden zu lesende Wörter kursiv geschrieben, und die zu ignorierenden Wörter werden in aufrechter Schrift in den kursiven Text eingestreut. In der Kontrollbedingung enthalten die Texte keine Distraktoren. Die Aufgabe der Probanden ist es, den kursiven Text laut vorzulesen und alle aufrechten Wörter in dem Text zu ignorieren. Die Zeit, die die Probanden benötigen, um den Text vollständig vorzulesen, wird erfasst. Nach jedem Text folgt ein Textverständnistest in Form eines *Multiple-Forced-Choice*-Rekognitionstests. Die Probanden bekommen mehrere Fragen zu dem Text gestellt. Als Antwortalternativen werden jeweils ein Zielwort (ein zuvor zu lesendes Wort), ein Distraktorwort (ein zuvor zu ignorierendes Wort) und neue Wörter dargeboten. Die Aufgabe des Probanden ist es, das zuvor zu lesende Zielwort aus diesen Antwortalternativen auszuwählen. Üblicherweise zeigt sich bei älteren Erwachsenen eine ausgeprägtere Lesezeitverlangsamung durch Distraktoren als bei jüngeren Erwachsenen (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Duchek, Balota, & Thessing, 1998; Dywan & Murphy, 1996; Kim, Hasher, & Zacks, 2007; Li, Hasher, Jonas, Rahhal, & May, 1998). Außerdem wird in manchen Studien beobachtet, dass das Textverständnis von älteren Erwachsenen stärker durch die Distraktoren beeinträchtigt ist und dass ältere Erwachsene öfter als jüngere Erwachsene das eigentlich zu ignorierende Distraktorwort auswählen (Carlson et al., 1995; Dywan & Murphy, 1996; Kemper, McDowd, Metcalf, & Liu, 2008). Die Größe der Altersunterschiede in der Verlangsamung durch Distraktoren wird maßgeblich durch die Ähnlichkeit der verwendeten Distraktoren zu dem zu lesenden Text determiniert. Die Altersunterschiede sind stärker ausgeprägt, wenn die Distraktoren semantisch auf den zu lesenden Text bezogen sind (Carlson et al., 1995; Li et al., 1998). Auf Basis der Inhibitionsdefizittheorie wurde als Erklärung für diesen Befund vorgeschlagen, dass semantisch auf den Text bezogene Distraktorwörter bei älteren Erwachsenen die Aufmerksamkeit stärker von der Leseaufgabe abziehen als andere Distraktoren, weil sie - einmal durch Defizite in der Zugangsfunktion in das Arbeitsgedächtnis gelangt - zu einer stärkeren Aktivierung von alternativen Interpretationen des gelesenen Textes führen, die gegeneinander abgewogen werden müssen (Carlson et al., 1995). Neben der semantischen Ähnlichkeit beeinflusst zudem die perzeptuelle Ähnlichkeit zwischen Distraktoren und zu lesendem Text die Größe der Altersunterschiede in der Lesezeitverlangsamung. Die altersbezogenen Unterschiede sind nicht vorhanden, wenn die Stellen im Text vorhersehbar sind, an denen die Distraktoren präsentiert werden (Carlson et al., 1995). Ähnlich wie bei früheren Befunden zum *Negative-Priming*-Effekt (Connelly & Hasher, 1993), wurde auch beim Lesen mit Distraktoren argumentiert, dass zwei unabhängige inhibitorische Systeme für die Unterdrückung von Reizidentität und Reizort existieren, von denen nur das System für die Reizidentitätsinhibition alterskorrelierte Defizite aufweist. Andere Untersuchungen finden ebenfalls keine Altersunterschiede in der Lesezeitverlangsamung, wenn Zieltext und Distraktorwörter beispielsweise durch verschiedene Schriftfarben perzeptuell gut voneinander unterscheidbar sind (Kemper & McDowd, 2006; Phillips & Lesperance, 2003). Allerdings modifizierten gerade diese Studien das ursprüngliche Paradigma sehr stark, indem beispielsweise einzelne Sätze statt ganzer Texte verwendet wurden, in die lediglich einmalig ein Distraktorwort oder eine Distraktorsequenz eingestreut wurde. Diese Prozedur erhöht wiederum die Vorhersehbarkeit der Distraktorposition. Daher kann das Ausbleiben von Altersunterschieden in der Lesezeitverlangsamung bei diesen Untersuchungen ebenso mit einem altersinvarianten inhibitorischen System für den Reizort erklärt werden. Im Allgemeinen entspricht demnach das Befundmuster hinsichtlich der Altersunterschiede in der distraktorinduzierten Lesezeitverlangsamung beim Lesen mit Distraktoren den Vorhersagen der Inhibitionsdefizittheorie. Daher wird das übliche Ergebnis - dass ältere Erwachsene durch Distraktoren stärker beim Lesen verlangsamt sind als jüngere Erwachsene - immer wieder als Evidenz für altersbedingte Defizite in der inhibitorischen Aufmerksamkeitskontrolle interpretiert und in Überblicksartikeln zitiert (Hasher et al., 2007; Lustig & Hasher, 2001; Lustig et al., 2001; Lustig et al., 2007; Zacks et al., 2000).

Allerdings ist die Interpretation der Befunde auch beim Lesen mit Distraktoren nicht so eindeutig, wie es zunächst scheinen mag. Auch in diesem Fall führen die Kritiker der Inhibitionsdefizittheorie eine Alternativerklärung an, die das Befundmuster genauso gut erklären kann wie die Inhibitionsdefizittheorie. So wurde postuliert, dass alle Altersunterschiede in der Interferenzanfälligkeit in diesem Paradigma auf altersbedingte sensorische Defizite zurückzuführen sind (Burke & Osborne, 2007; Burke & Shafto, 2008). Diese Auffassung erscheint plausibel, denn in der Tat erfordert die Aufgabe die Unterscheidung von subtilen perzeptuellen Unterschieden im Schriftstil. Außerdem ist bekannt, dass das Altern mit einer Vielzahl von Veränderungen im visuellen System einhergeht, die nicht mit einer externen Sehhilfe kompensiert werden können und die eine Reduktion der Sehschärfe älterer Erwachsener bedingen (Fozard, 1990; Schieber, 1992). Somit liegt die Annahme nahe, dass ältere Erwachsene zumindest gelegentlich den Unterschied zwischen aufrechten Distraktorwörtern und kursiven Zieltextwörtern nicht erkennen können und daher die Distraktorwörter mit einer größeren Wahrscheinlichkeit verarbeiten als jüngere Erwachsene. Aufgrund der offensichtlichen Möglichkeit eines solchen direkten Einflusses der Sehschärfe auf die Ablenkbarkeit beim Lesen mit Distraktoren scheint es umso verwunderlicher, dass keine der aufgeführten Studien die Sehschärfe der Probanden kontrolliert hat oder auch nur berichtet. Daher existiert kein empirischer Anhaltspunkt über die faktische Bedeutsamkeit der Sehschärfeproblematik. Aufgrund der erheblichen altersbedingten Veränderungen im visuellen System lässt sich aber vermuten, dass zumindest ein Teil der in den einschlägigen Studien berichteten Altersunterschiede statt auf Defiziten in der Interferenzkontrolle eigentlich auf altersbedingte Defizite in der Sehschärfe zurückzuführen ist. Dieser alternative Erklärungsansatz für die Altersunterschiede beim Lesen mit Distraktoren könnte außerdem erklären, weshalb die Altersunterschiede in der Ablenkbarkeit beim Lesen mit Distraktoren geringer werden oder sogar gar nicht mehr vorhanden sind, wenn Zieltext und Distraktorwörter durch eine andere Schriftart gut voneinander zu unterscheiden sind oder wenn sich die Distraktorwörter an vorhersehbaren Positionen befinden (Carlson et al., 1995; Kemper & McDowd, 2006; Phillips & Lesperance, 2003). Darüber hinaus könnte der Einfluss der semantischen Ähnlichkeit zwischen Zieltext und Distraktoren auf die Größe der Altersunterschiede beim Lesen mit Distraktoren ebenfalls durch altersbedingte sensorische Defizite erklärt werden. Wenn man annimmt, dass die Differenzierung von zu lesendem Text und Distraktoren bei älteren Erwachsenen auf perzeptueller Ebene beeinträchtigt ist, verlassen sich ältere Erwachsene möglicherweise stärker als jüngere Erwachsene auf den semantischen Kontext um zu entscheiden, ob es sich bei dem jeweiligen Wort um ein zu lesendes Wort oder um ein Distraktorwort handelt. Sofern jedoch auch die Semantik nicht zwischen beiden Wortkategorien differenziert, wären ältere Erwachsene auch durch sensorische Defizite in besonderem Maße von der Interferenz durch semantisch assoziierte Distraktoren betroffen. Offenkundig können demnach sowohl inhibitorische als auch sensorische Defizite im höheren Lebensalter das gesamte Befundmuster einer der wichtigsten empirischen Stützen für die Inhibitionsdefizittheorie erklären. Somit ist für die Beurteilung des Gültigkeitsumfangs der Inhibitionsdefizittheorie die Überprüfung der Frage unerlässlich, ob die Altersunterschiede beim Lesen mit Distraktoren ausschließlich auf alterskorrelierten Defiziten in der Sehschärfe beruhen, oder ob sie tatsächlich aus Defiziten in höheren kognitiven Prozessen - wie ineffektiven inhibitorischen Aufmerksamkeitsmechanismen - resultieren.

Doch die Vernachlässigung von altersbedingten sensorischen Defiziten als potenzielle Ursache für die gefundenen Altersunterschiede in der Interferenzanfälligkeit stellt nicht den einzigen zu kritisierenden Aspekt in der Methodik der bisherigen Studien zum Lesen mit Distraktoren dar. Insbesondere stechen Punkte hervor, die primär mit der konkreten Operationalisierung der eigentlich zu erfassenden Variablen und demnach mit der konkreten Umsetzung der Aufgabe zusammen hängen. Bei genauerer Betrachtung der Ergebnisse hinsichtlich der Altersunterschiede in der Beeinträchtigung des Textverständnisses durch Distraktoren zeigt sich im Gegensatz zu den Lesezeiten ein uneinheitliches Datenmuster (siehe Tabelle 1 in Artikel 2). Lediglich zwei von elf Studien zeigten eine stärkere Beeinträchtigung von älteren Erwachsenen in den Experimentalbedingungen bezüglich der Fähigkeit, das Zielwort korrekt auszuwählen. Zugleich zeigten nur zwei von sieben Studien einen Anstieg von fälschlicherweise ausgewählten Distraktorwörtern bei älteren Erwachsenen[1]. Prinzipiell wären somit auch die Ergebnisse des Rekognitionstests mit der Annahme vereinbar, dass faktisch keine altersbezogenen Einbußen in der inhibitorischen Aufmerksamkeitskontrolle existieren (Burke, 1997; Burke & Osborne, 2007). Stattdessen könnte das Zusammenspiel von Alpha-Fehler und Publikationsbias in Richtung der Veröffentlichung von (statistisch) „signifikanten" Ergebnissen das Datenmuster des Rekognitionstests erklären. Jedoch sind auch Alternativerklärungen für die Inkonsistenzen vorstellbar, die mit der Annahme eines altersbedingten Inhibitionsdefizits gut vereinbar sind. Beispielsweise zeigte sich, dass der verwendete Rekognitionstest über eine äußerst geringe Reliabilität verfügt (mit Cronbach-Alpha-Koeffizienten von .41 bis .42; Darowski et al., 2008), so dass die uneinheitliche Befundlage auch auf die geringe Reliabilität des Testverfahrens statt auf erhaltene Inhibitionsfunktionen zurückzuführen sein könnte. Doch einer der möglicherweise gravierendsten potentiellen Gründe für die Inkonsistenz ist, dass ein Rekognitionstest eher die Erinnerung an oberflächliche Merkmale eines Textes prüft. Allerdings sind die meisten Textverarbeitungsmodelle in ihrer Grundannahme konform, dass die Bedeutung eines Textes in einer mentalen Repräsentation abgespeichert wird, die ein semantisches Netzwerk aus aktivierten Wortkonzepten und Propositionen darstellt (McNamara & Magliano, 2009). Eine solche mentale Textrepräsentation lässt sich beispielsweise mit einer freien Reproduktionsaufgabe erfassen (Srinivas & Roediger, 1990). Allerdings wurden die Altersunterschiede in der Beeinträchtigung des Textverständnisses beim Lesen mit Distraktoren bislang noch nie mit einem Verfahren untersucht, das die mentale Repräsentation eines Textes erfassen kann. Diese Tatsache ist problematisch, da auch die Interpretation der reliabel gefundenen Altersunterschiede in den Lesezeiten ohne einen geeigneten Textverständnistest aus verschiedenen Gründen uneindeutig ist. Beispielsweise könnten Altersunterschiede im Geschwindigkeits-Genauigkeits-Ausgleich (Brébion, 2001, 2003) dazu führen, dass ältere Erwachsene gerade in den Bedingungen langsamer lesen, in denen der Aufbau einer kohärenten mentalen Textrepräsentation durch die Distraktoren erschwert wird.

Eine weitere Schwierigkeit bei der Auslegung des ausgeprägteren Lesezeitanstiegs bei älteren Erwachsenen als Evidenz für ein altersbedingtes Inhibitionsdefizit ist, dass ältere Erwachsene bereits in der Kontrollbedingung langsamer lesen als jüngere Erwachsene. Da ältere Erwachsene gewöhnlich in einer Vielzahl von kognitiven Aufgaben verlangsamt sind, wird in der Regel eine allgemeine altersbedingte kognitive Verlangsamung (Salthouse, 1996) bei der Auswertung von Reaktionszeiten berücksichtigt (Gamboz et al., 2002; Verhaeghen & De Meersman, 1998). Hinsichtlich des Lesens mit Distraktoren beinhaltet dies, dass dem Test auf Altersunterschiede in der Lesezeitverlangsamung durch Distraktoren zusätzlich eine andere Nullhypothese zugrunde gelegt werden sollte: Anstatt ausschließlich zu überprüfen, ob Altersunterschiede in der Differenz zwischen der Lesezeit in der Kontrollbedingung und der Lesezeit in der Experimentalbedingung existieren, sollte überdies eine proportionale Auswertung verwendet werden. Bei der proportionalen Auswertung wird getestet, ob sich die Relation von Lesezeitanstieg in der Experimentalbedingung zur Lesezeit in der Kontrollbedingung zwischen älteren und jüngeren Erwachsenen unterscheidet. Somit kann kontrolliert werden, ob der Lesezeitanstieg in den Experimentalbedingungen lediglich aus einer generellen Verlangsamung der älteren Erwachsenen resultiert, die sich als multiplikativer Faktor in den Lesezeiten zeigen würde. Nur in einer bisherigen Studie wird eine proportionale Auswertung der Lesezeiten berichtet (Kim et al., 2007), bei der sich zeigte, dass der Altersunterschied in der Lesezeitverlangsamung nicht bestehen blieb[2]. Diese Tatsache verdeutlicht abermals, dass die Ergebnisse der Lesezeiten für sich allein genommen wenig aussagekräftig sind. Darüber hinaus ist verwunderlich, dass in den meisten Studien die mittlere Lesezeit für einen gesamten Text zur Beurteilung von Altersunterschieden in der Interferenzanfälligkeit herangezogen wird, obwohl die Inhibitionsdefizittheorie die Herleitung weitaus spezifischerer Hypothesen bezüglich der einzelnen Wortkategorien (Zieltextwörter und Distraktorwörter) erlaubt.

Folglich erweist sich die bisher angewandte Methodik zur Untersuchung von Altersunterschieden in der Ablenkbarkeit beim Lesen mit Distraktoren insgesamt als suboptimal. Neben der Missachtung von sensorischen Defiziten als potentieller Ursache für die Altersunterschiede wird ein ungeeigneter Textverständnistest verwendet. Überdies basiert die Argumentation zugunsten der Inhibitionsdefizittheorie maßgeblich auf der relativ unpräzisen Messung der mittleren Lesezeit für einen Text. Somit ist völlig unklar, ob die Altersunterschiede in der Interferenzanfälligkeit beim Lesen mit Distraktoren tatsächlich auf ein altersbedingtes Inhibitionsdefizit zurückzuführen sind. Dieser Frage widmet sich die vorliegende Arbeit in vier Einzelexperimenten. In Experiment 1 wurde überprüft, ob sich die Altersunterschiede in der Interferenzanfälligkeit bei jüngeren Erwachsenen simulieren lassen, wenn ihre Sehschärfe künstlich auf die Sehschärfe älterer Erwachsener reduziert wird (Artikel 1). In Experiment 2 wurde untersucht, ob die Altersunterschiede in der Ablenkbarkeit durch Distraktoren bestehen bleiben, wenn ältere und jüngere Erwachsene über dieselben sensorischen Grundvorraussetzungen hinsichtlich der Sehschärfe verfügen (Artikel 1). In Experiment 3 wurde der klassische Rekognitionstest durch eine freie Reproduktionsaufgabe ersetzt. Es sollte überprüft werden, ob sich Altersunterschiede in der Beeinträchtigung des Textverständnisses zeigen, wenn man ein Testverfahren verwendet, das dazu geeignet ist, die mentale Repräsentation eines Textes zu erfassen (Artikel 2). In Experiment 4 wurden spezifischere Hypothesen der Inhibitionsdefizittheorie hinsichtlich der Lesezeiten für einzelne Wortkategorien mit Hilfe der *Moving-Window*-Methode untersucht (Artikel 3). Unter Annahme eines allgemeinen Inhibitionsdefizits als Erklärung für die Altersunterschiede beim Lesen mit Distraktoren würde man erwarten, dass sich Altersunterschiede in der Ablenkbarkeit unter allen Manipulationen zeigen. Da der Aufbau, der Ablauf, sowie die Ergebnisse der Experimente in Artikel 1, Artikel 2 und Artikel 3 im Detail beschrieben sind, soll im Folgenden nur ein kurzer Überblick gegeben werden.

Experiment 1

In Experiment 1 wurde überprüft, ob sich die Altersunterschiede in der Interferenzanfälligkeit bei jüngeren Erwachsenen simulieren lassen, wenn ihre Sehschärfe künstlich auf die Sehschärfe älterer Erwachsener reduziert wird. Zur Visusreduktion wurden so genannte partielle Okklusionsfolien (Ryser Optik; St. Gallen, Schweiz) verwendet. Die trübende Eigenschaft der Folien ähnelt der eines Milchglases. Sie wird mithilfe eingearbeiteter Streuungsprismen erzeugt und stellt eine Möglichkeit dar, die Sehschärfe von normalsichtigen Probanden künstlich zu verringern. Bei der Produktion dieser Folien können unterschiedliche Trübungsgrade erreicht werden. Somit existieren Folien unterschiedlicher Stärken, welche die Sehschärfe einer Versuchsperson mit einem ursprünglichen Visus von 1.0 auf einen angegebenen Wert reduzieren. Beispielsweise wird von einer Folie mit der Bezeichnung 0.8 eine Sehschärfereduktion auf einen Visus von 0.8 erwartet. In Experiment 1 wurden Folien der Stärke 0.4 verwendet, welche am ehesten der altersbedingten Sehschärfereduktion entsprechen sollten (Lindenberger, Scherer, & Baltes, 2001). Insgesamt durchliefen drei Gruppen das Experiment: 1) jüngere Erwachsene (im Alter von 18 - 30 Jahren) mit normaler Sehschärfe, 2) jüngere Erwachsene (im Alter von 18 - 30 Jahren) mit reduzierter Sehschärfe und 3) ältere Erwachsene (im Alter von 60 - 83 Jahren) mit normaler Sehschärfe. Das Experiment entsprach hinsichtlich seines Ablaufes und seiner Materialien den üblichen Experimenten zum Lesen mit Distraktoren. Die Probanden sollten zwölf Texte von je 120 Wörtern sowohl möglichst zügig als auch möglichst fehlerfrei vorlesen. Die Texte wurden auf einem Computermonitor präsentiert. Die Lesezeit des jeweiligen Textes wurde vom Versuchsleiter mit Hilfe der Computertastatur gestoppt. Eine Hälfte der Texte wurde in der Kontrollbedingung präsentiert und enthielt Lücken (Distraktorbedingung „Lücken“), die andere Hälfte der Texte wurde in der Experimentalbedingung präsentiert und enthielt semantisch zu dem Zieltext assoziierte Distraktorwörter (Distraktorbedingung „Assoziierte Distraktoren“). Die Zuordnung der Texte zu den zwei Distraktorbedingungen erfolgte für jede Versuchsperson zufällig. In jedem Text wurden für fünf Substantive zwei ähnliche Nomen (meistens Synonyme) bestimmt, welche die ursprünglichen Substantive ersetzen konnten ohne dabei die Bedeutung des Satzes zu verändern. Für jede Versuchsperson wurde zufällig bestimmt, a) welche dieser drei Alternativen als kursives Zielwort an der korrekten Position im Text erscheinen würde, b) welches Wort in der Experimentalbedingung als aufrechtes Distraktorwort verwendet und an zehn zufällig ausgewählten Positionen in den Zieltext eingestreut werden würde und c) welches Wort erst in einem späteren Rekognitionstest als neues Wort präsentiert werden würde. Insgesamt enthielt ein Text in der Experimentalbedingung somit 50 Distraktorwörter (5 verschiedene Distraktoren; jeweils zehn Mal in den Text eingestreut). Nach jedem Text folgte ein *Multiple-Forced-Choice* Rekognitionstest, der an die Textverständnistests der früheren Studien angelehnt war. Hierbei wurden den Probanden das Zielwort, das Distraktorwort und das neue Wort als Antwortalternativen präsentiert, wobei sie aus diesen Alternativen das zuvor präsentierte Zielwort auswählen sollten. Erfasst wurde die Anzahl korrekt ausgewählter Zielwörter und die Anzahl fälschlicherweise ausgewählter Distraktorwörter in der Experimentalbedingung (Intrusionsfehler).

Abbildung 1 stellt die Ergebnisse hinsichtlich der Lesezeiten grafisch dar. Das gängige Befundmuster konnte repliziert werden: Ältere Erwachsene mit normaler Sehschärfe waren stärker durch in den Text eingestreute Distraktoren verlangsamt als jüngere Erwachsene mit normaler Sehschärfe.

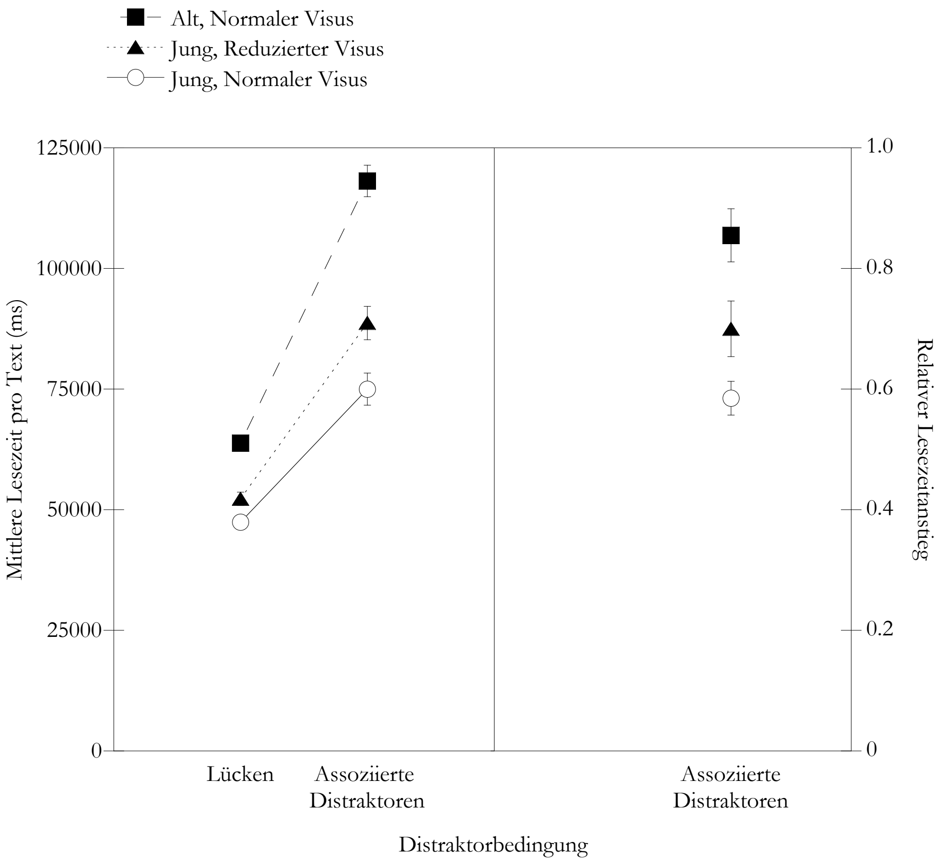

Abbildung 1: Lesezeiten in Experiment 1. Linke Seite: Mittlere Lesezeiten für einen gesamten Text als Funktion von Distraktorbedingung und Gruppe. Rechte Seite: Mittlerer proportionaler Lesezeitanstieg in der Distraktorbedingung Assoziierte Distraktoren relativ zu der Distraktorbedingung Lücken. Die Fehlerbalken kennzeichnen die Standardfehler der Mittelwerte.

Überdies zeigte sich, dass sensorische Defizite einen Einfluss auf die Ablenkbarkeit beim Lesen mit Distraktoren haben können, da die Verlangsamung in der Experimentalbedingung bei jüngeren Erwachsenen mit reduzierter Sehschärfe stärker ausgeprägt war als bei jüngeren Erwachsenen mit normaler Sehschärfe. Der für die aktuelle Fragestellung bedeutsamste Aspekt ist jedoch, dass ältere Erwachsene auch im Vergleich zu jüngeren Erwachsenen mit reduzierter Sehschärfe einen stärkeren Lesezeitanstieg in der Experimentalbedingung zeigten, obwohl jüngere Erwachsene nach der Visusreduktion sogar über eine geringere Sehschärfe verfügten (der Median der Verteilung lag bei einem Visuswert von 0.4) als ältere Erwachsene (der Median der Verteilung lag bei einem Visuswert von 0.6). Somit zeigte sich, dass altersbedingte sensorische Defizite keine ausschließliche Erklärung für den ausgeprägteren Lesezeitanstieg älterer Erwachsener beim Lesen mit Distraktoren darstellen. Bei einer anschließenden proportionalen Auswertung der Lesezeiten blieben die Gruppenunterschiede in der Lesezeitverlangsamung durch assoziierte Distraktoren erhalten[3]. Daher stellt eine allgemeine kognitive Verlangsamung um einen multiplikativen Faktor keine adäquate Erklärung für die Gruppenunterschiede dar.

Tabelle 1 und Tabelle 2 führen die Ergebnisse des Rekognitionstests auf. Weder hinsichtlich der Anzahl korrekt ausgewählter Zielwörter (Tabelle 1) noch bezüglich der Anzahl von Intrusionsfehlern (Tabelle 2) fanden sich Altersunterschiede in der Beeinträchtigung durch Distraktoren. Die Reduktion der Sehschärfe hatte keinen Einfluss auf die Leistung der Probanden im Rekognitionstest.

Tabelle 1: Relative Häufigkeit korrekt ausgewählter Zielwörter als Funktion von Gruppe (Spalten) und Distraktorbedingung (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung, Normaler Visus	Jung, Reduzierter Visus	Alt, Normaler Visus
Lücken	. 71 (. 01)	. 74 (. 01)	. 61 (. 01)
Assoziierte Distraktoren	. 58 (. 02)	. 59 (. 02)	. 46 (. 02)

Tabelle 2: Relative Häufigkeit von Fehlern in der Distraktorbedingung Assoziierte Distraktoren als Funktion von Gruppe (Spalten) und Fehlertyp (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung, Normaler Visus	Jung, Reduzierter Visus	Alt, Normaler Visus
Distraktoren	. 32 (. 02)	. 32 (. 02)	. 40 (. 02)
Neue Wörter	. 10 (. 01)	. 09 (. 01)	. 14 (. 01)

Experiment 2

In Experiment 1 wurde der Visus von jüngeren Erwachsenen drastisch reduziert, um die Vergleichbarkeit zwischen der aktuellen Arbeit und der Studie von Lindenberger et al. (2001) zu gewährleisten. Laut Lindenberger et al. wird eine Sehschärfe von 0.4 üblicherweise in Stichproben von gesunden Senioren beobachtet. Wie sich jedoch zeigte, waren nicht alle älteren Probanden gleichermaßen von der altersbedingten Reduktion der Sehschärfe betroffen. Somit führt eine Sehschärfereduktion mit einer einzigen Okklusionsfolienstärke nicht zu einer genauen Übereinstimmung der Sehschärfe von jüngeren und älteren Erwachsenen. In Experiment 2 wurde daher die Sehschärfe von sowohl jüngeren als auch älteren Erwachsenen auf Visuswerte im Bereich zwischen 0.4 und 0.6 reduziert. Zu diesem Zweck wurden nun in Abhängigkeit von der ursprünglichen Sehschärfe des jeweiligen Probanden Okklusionsfolien verschiedener Stärken verwendet, so dass jeder Proband nach der Sehschärfereduktion einen Visuswert im Bereich zwischen 0.4 und 0.6 aufwies. Somit verfügten ältere und jüngere Erwachsene über dieselben sensorischen Grundvorraussetzungen hinsichtlich der Sehschärfe. In Experiment 2 sollte überprüft werden, ob die Altersunterschiede in der Interferenzanfälligkeit beim Lesen mit Distraktoren unter diesen Umständen bestehen bleiben.

Insgesamt durchliefen vier Gruppen das Experiment: 1) jüngere Erwachsene (im Alter von 19 - 30 Jahren) mit normaler Sehschärfe, 2) ältere Erwachsene (im Alter von 62 - 85 Jahren) mit normaler Sehschärfe, 3) jüngere Erwachsene (im Alter von 19 - 30 Jahren) mit reduzierter Sehschärfe und 4) ältere Erwachsene (im Alter von 60 - 81 Jahren) mit reduzierter Sehschärfe. Sowohl Aufbau als auch Ablauf des Experiments waren identisch zu Experiment 1. Darüber hinaus wurden noch eine Kontrollbedingung mit durchgehendem Text (Distraktorbedingung „Fließtext“) und eine Kontrollbedingung, in der zufällig ausgewählte Buchstabenfolgen als Distraktoren dienten (Distraktorbedingung „Zufallsbuchstaben“) als zusätzliche Distraktorbedingungen aufgenommen. Mit dieser Modifikation sollte überprüft werden, inwieweit bereits das Ignorieren von Folgen aus Zufallsbuchstaben oder das Lesen von unterbrochenen Texten zu einer ähnlichen Erhöhung der Lesezeit führen wie semantisch assoziierte Distraktorwörter, oder ob die Interferenz tatsächlich auf lexikalisch-semantischer Ebene stattfindet. Jeweils fünf Texte wurden zufällig den insgesamt vier Bedingungen zugeordnet, so dass den Probanden insgesamt zwanzig Texte präsentiert wurden. Um die Dauer der Testungen nicht wesentlich zu verlängern, enthielten die Texte im Gegensatz zu Experiment 1 lediglich 60 Wörter. Daher wurden auch nur für drei Substantive des jeweiligen Textes ähnliche Nomen für die zufällige Selektion als Distraktoren oder als Neue Wörter bestimmt, so dass das Verhältnis von Distraktoren und zu lesendem Text in Experiment 1 und in Experiment 2 vergleichbar war. Jedes der drei als Distraktoren ausgewählten Substantive wurde in der Experimentalbedingung erneut an zehn zufällig bestimmten Positionen in den jeweiligen Zieltext eingestreut.

Die grafische Darstellung der Lesezeiten für die beiden Altersgruppen mit normaler Sehschärfe findet sich in Abbildung 2, während Abbildung 3 die Lesezeiten der beiden Altersgruppen mit reduzierter Sehschärfe illustriert. Konsistent mit früheren Befunden zeigten ältere Erwachsene eine stärkere Verlangsamung durch Distraktoren als jüngere Erwachsene. Überdies erhöhte die künstliche Reduktion der Sehschärfe für beide Altersgruppen die Lesezeitverlangsamung in der Experimentalbedingung. Insbesondere ist für die gegenwärtige Fragestellung jedoch bedeutsam, dass die Altersunterschiede hinsichtlich des Lesezeitanstiegs durch assoziierte Distraktoren infolge der Visusreduktion weder eliminiert noch verringert wurden. Ältere Erwachsene zeigten stets einen ausgeprägteren Lesezeitanstieg als jüngere Erwachsene - unabhängig davon, ob beide Altersgruppen über dieselben sensorischen Grundvoraussetzungen hinsichtlich der Sehschärfe verfügten oder nicht.

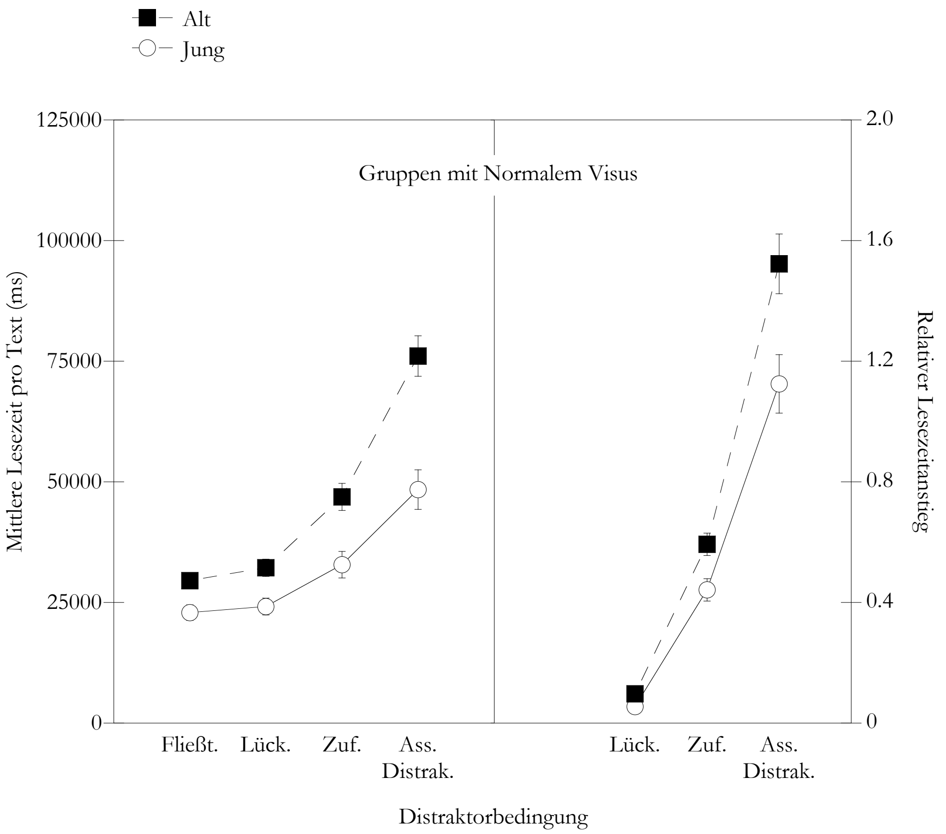

Abbildung 2: Lesezeiten der Gruppen mit normaler Sehschärfe in Experiment 2. Linke Seite: Mittlere Lesezeiten für einen gesamten Text als Funktion von Distraktorbedingung und Gruppe. Rechte Seite: Mittlerer proportionaler Lesezeitanstieg in den Distraktorbedingungen Lücken (Lück.), Zufallsbuchstaben (Zuf.) und Assoziierte Distraktoren (Ass. Distrak.) relativ zu der Distraktorbedingung Fließtext (Fließt.). Die Fehlerbalken kennzeichnen die Standardfehler der Mittelwerte.

Konsistent zu Experiment 1 blieben bei einer zusätzlichen proportionalen Auswertung der Lesezeiten die Altersunterschiede in der Lesezeitverlangsamung durch assoziierte Distraktoren bestehen. In den Kontrollbedingungen jedoch waren die Altersunterschiede bei den Gruppen mit künstlicher Sehschärfereduktion nicht mehr vorhanden. Dies zeigt, dass die Interferenz beim Lesen mit Distraktoren tatsächlich auf semantischer Ebene stattfindet und dass sowohl Lücken als auch Zufallsbuchstaben adäquate Kontrollbedingungen darstellen, sofern Altersunterschiede in der Sehschärfe kontrolliert werden und eine allgemeine kognitive Verlangsamung bei der Auswertung berücksichtigt wird.

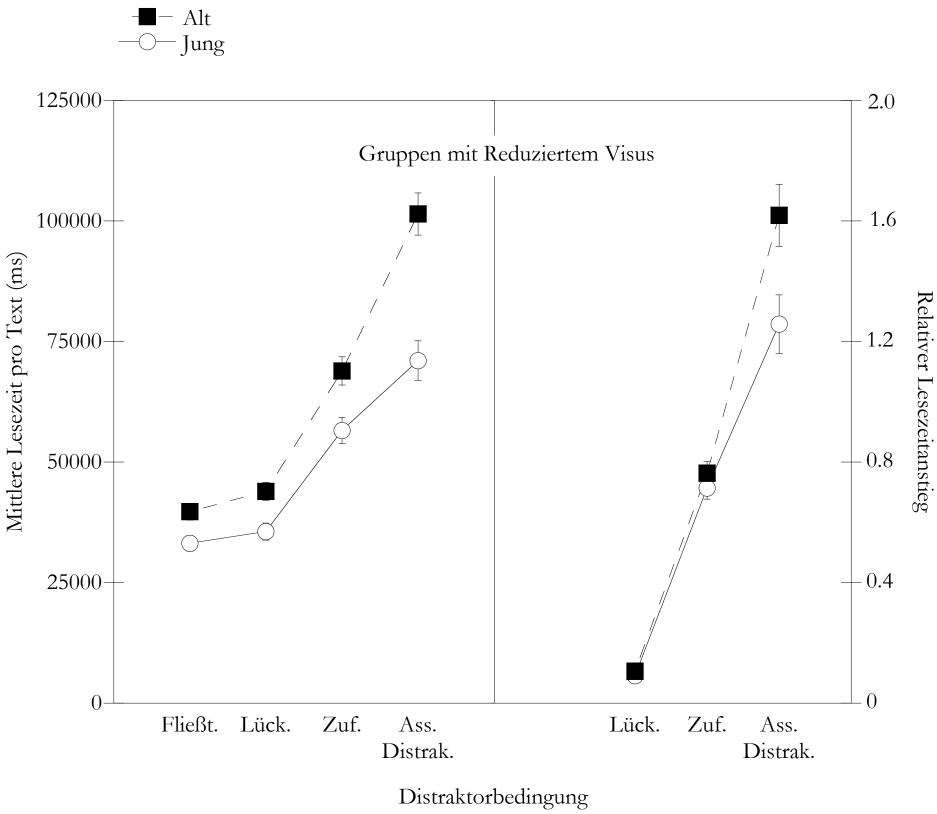

Abbildung 3: Lesezeiten der Gruppen mit reduzierter Sehschärfe in Experiment 2. Linke Seite: Mittlere Lesezeiten für einen gesamten Text als Funktion von Distraktorbedingung und Gruppe. Rechte Seite: Mittlerer proportionaler Lesezeitanstieg in den Distraktorbedingungen Lücken (Lück.), Zufallsbuchstaben (Zuf.) und Assoziierte Distraktoren (Ass. Distrak.) relativ zu der Distraktorbedingung Fließtext (Fließt.). Die Fehlerbalken kennzeichnen die Standardfehler der Mittelwerte.

Die Ergebnisse des Rekognitionstests sind in Tabelle 3 und Tabelle 4 aufgeführt. Äquivalent zu Experiment 1 fanden sich keine Altersunterschiede hinsichtlich der Anzahl korrekt ausgewählter Zielwörter (Tabelle 3). Jedoch unterliefen älteren Erwachsenen in der Experimentalbedingung nun mehr Intrusionsfehler als jüngeren Erwachsenen (Tabelle 4). Diese Diskrepanz könnte auf die etwas höhere Teststärke in Experiment 2 im Vergleich zu Experiment 1 zurückgeführt werden. Da der Rekognitionstest über eine ähnlich geringe Reliabilität wie in vorherigen Studien verfügte (mit Cronbach-Alpha-Koeffizienten von .40 bis .48 in den verschiedenen Distraktorbedingungen), ist anzunehmen, dass aufgrund der durch die geringe Reliabilität erhöhten Fehlervarianz eine höhere Teststärke nötig ist, um einen vorhandenen Effekt aufzudecken. Die Reduktion der Sehschärfe hatte dagegen abermals keinen Einfluss auf die Leistung im Rekognitionstest.

Tabelle 3: Relative Häufigkeit korrekt ausgewählter Zielwörter als Funktion von Gruppe (Spalten) und Distraktorbedingung (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung, Normaler Visus	Jung, Reduzierter Visus	Alt, Normaler Visus	Alt, Reduzierter Visus
Fließtext	. 82 (. 02)	. 81 (. 02)	. 67 (. 02)	. 67 (. 02)
Lücken	. 78 (. 02)	. 82 (. 02)	. 70 (. 02)	. 69 (. 02)
Zufallsbuchstaben	. 82 (0.2)	. 85 (. 02)	. 71 (. 02)	. 71 (. 02)
Assoziierte Distraktoren	. 58 (. 02)	. 59 (. 02)	. 44 (. 02)	. 40 (. 02)

Tabelle 4: Relative Häufigkeit von Fehlern in der Distraktorbedingung Assoziierte Distraktoren als Funktion von Gruppe (Spalten) und Fehlertyp (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung, Normaler Visus	Jung, Reduzierter Visus	Alt, Normaler Visus	Alt, Reduzierter Visus
Distraktoren	. 37 (. 02)	. 37 (. 02)	. 47 (. 02)	. 52 (. 02)
Neue Wörter	. 05 (. 01)	. 04 (. 01)	. 09 (. 01)	. 08 (. 01)

Aufgrund der Ergebnisse von Experiment 1 und Experiment 2 lässt sich feststellen, dass eine verminderte Sehschärfe die Lesezeitverlangsamung durch Distraktoren erhöht. In Studien, in denen der Visus der Probanden nicht erfasst wird und ältere und jüngere Erwachsene sich daher in unbekanntem Ausmaß in ihrer Sehschärfe unterscheiden, wäre es theoretisch also möglich, dass Altersunterschiede in der Interferenzanfälligkeit überschätzt werden. Daher sollte die Sehschärfe in künftigen Studien zum Lesen mit Distraktoren dringend kontrolliert werden. Allerdings hatte die künstliche Reduktion der Sehschärfe keinen Einfluss auf das Auftreten der Altersunterschiede in der Interferenzanfälligkeit, die somit auf altersbedingten Defiziten in höheren kognitiven Funktionen zu beruhen scheinen.

Experiment 3

In Experiment 3 sollte überprüft werden, ob sich Altersunterschiede in der Interferenzanfälligkeit auch in einer stärkeren Beeinträchtigung des Textverständnisses von älteren Erwachsenen zeigen, wenn statt eines Rekognitionstests eine freie Reproduktionsaufgabe verwendet wird. Insgesamt nahmen 2 Gruppen an dem Experiment teil: 1) jüngere Erwachsene (im Alter von 19 - 30 Jahren) und 2) ältere Erwachsene (im Alter von 60 - 82 Jahren). Um ein Überschätzen der Altersunterschiede in den kognitiven Fähigkeiten zu vermeiden, wurde die Sehschärfe der jüngeren Erwachsenen künstlich auf den Wert eines zufällig zugeteilten älteren Erwachsenen reduziert. Somit verfügten jüngere und ältere Erwachsene im eigentlichen Experiment wie in Experiment 2 über dieselben sensorische Grundvoraussetzungen hinsichtlich ihrer Sehschärfe, ohne dass der Visus der älteren Erwachsenen künstlich reduziert wurde. Die verwendeten Materialien entsprachen denen aus Experiment 2. Allerdings wurden nun eine Kontrollbedingung (Distraktorbedingung „Fließtext") und zwei Experimentalbedingungen (Distraktorbedingung „Nicht-Assoziierte Distraktoren" und Distraktorbedingung „Assoziierte Distraktoren") verwendet. Mit Hilfe dieser zusätzlichen Experimentalbedingung sollte überprüft werden, ob die in den Distraktoren enthaltene Information in die mentale Repräsentation der Texte integriert wird. Den Probanden wurden fünfzehn der insgesamt zwanzig Texte präsentiert. Den verbleibenden fünf Texten wurden die nicht-assoziierten Distraktoren für die zusätzliche Experimentalbedingung entnommen. Die Zuordnung der Texte zu den Bedingungen sowie die Zuordnung der Substantive zu der jeweiligen Wortkategorie (Distraktorwort oder Zielwort) erfolgte wie in den ersten beiden Experimenten für jeden Probanden zufällig. Die Substantive, die weder als Distraktorwort noch als Zielwort ausgewählt worden waren, dienten als Kontrollwörter für die Intrusionsfehler. Anstelle des in Experiment 1 und Experiment 2 verwendeten Rekognitionstests folgte nach jedem Text die freie Reproduktionsphase. Hier wurden die Probanden aufgefordert, den soeben gelesenen Text möglichst detailliert wieder zu geben. Ausgewertet wurde die Anzahl korrekt reproduzierter Propositionen. Die Wiedergabe eines Distraktorwortes wurde als Intrusion von Distraktoren gewertet, die Wiedergabe eines Kontrollwortes als Intrusion von Kontrollwörtern.

Abbildung 4 stellt die Ergebnisse hinsichtlich der Lesezeiten grafisch dar. Erneut zeigte sich das klassische Befundmuster, dass ältere Erwachsene stärker durch in den Text eingestreute Distraktoren verlangsamt waren als jüngere Erwachsene. Zwischen beiden Experimentalbedingungen zeigte sich kein Unterschied in der altersbezogenen Lesezeitverlangsamung. Interessanterweise existierte im gegenwärtigen Experiment überdies kein Altersunterschied in der Kontrollbedingung. Da die freie Reproduktionsaufgabe statt der Erinnerung an oberflächliche Merkmale die mentale Repräsentation des Textes erfasst (Srinivas & Roediger, 1990), deutet dieser Befund möglicherweise an, dass beide Altersgruppen vor diesem Hintergrund ihren Leseschwerpunkt auf den Aufbau einer mentalen Textrepräsentation legten. Von wesentlich größerer Bedeutung ist jedoch, dass aufgrund des Ausbleibens der Altersunterschiede in der Kontrollbedingung eine allgemeine kognitive Verlangsamung keine adäquate Erklärung für die Altersunterschiede in der Lesezeitverlangsamung in den Experimentalbedingungen darstellen kann. Dies wurde durch die anschließende Auswertung der proportionalen Lesezeiten bestätigt, bei der die Altersunterschiede in der Ablenkbarkeit bestehen blieben.

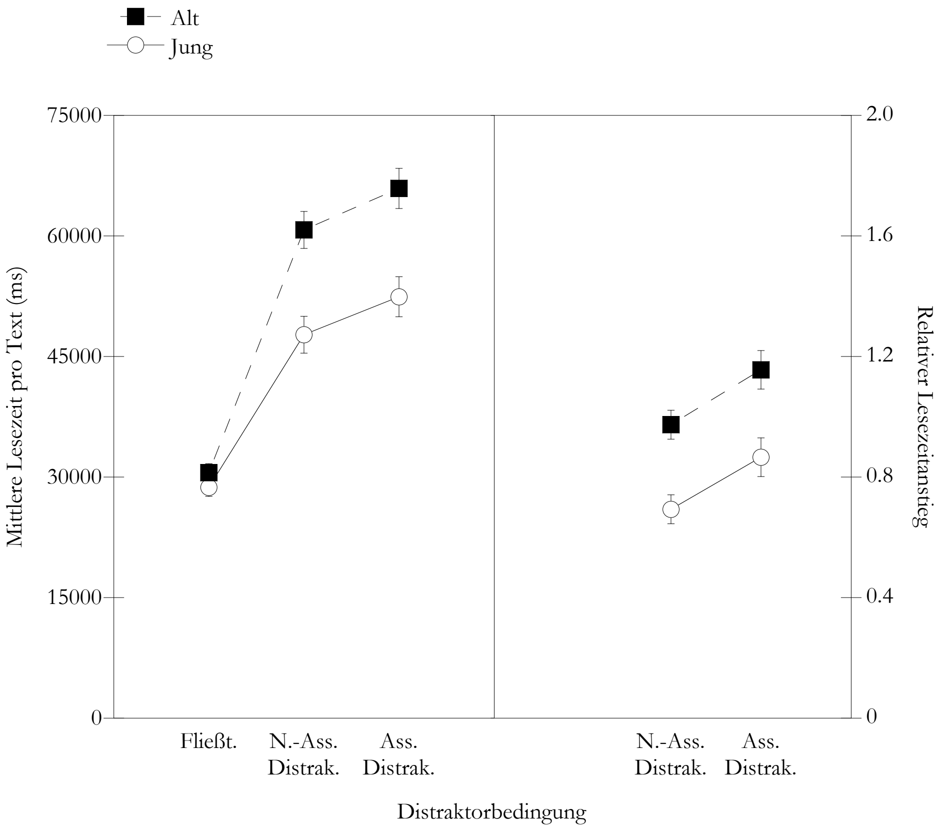

Abbildung 4: Lesezeiten in Experiment 3. Linke Seite: Mittlere Lesezeiten für einen gesamten Text als Funktion von Distraktorbedingung und Gruppe. Rechte Seite: Mittlerer proportionaler Lesezeitanstieg in den Distraktorbedingungen Nicht-Assoziierte Distraktoren (N.-Ass. Distrak.) und Assoziierte Distraktoren (Ass. Distrak.) relativ zu der Distraktorbedingung Fließtext (Fließt.). Die Fehlerbalken kennzeichnen die Standardfehler der Mittelwerte.

Die Ergebnisse der freien Reproduktion sind in Tabelle 5 und Tabelle 6 aufgeführt. Konsistent mit den Vorhersagen der Inhibitionsdefizittheorie manifestierten sich bei Verwendung eines geeigneteren Textverständnistests mit einer höheren Reliabilität (mit Cronbach-Alpha-Koeffizienten von .71 bis .79 in den verschiedenen Distraktorbedingungen) Altersunterschiede in der Beeinträchtigung des Textverständnisses durch Distraktoren. Die Anzahl reproduzierter Propositionen war bei älteren Erwachsenen in beiden Experimentalbedingungen stark reduziert (Tabelle 5). Zudem unterliefen älteren Erwachsenen in beiden Experimentalbedingungen mehr Intrusionen von Distraktoren als jüngeren Erwachsenen. Die Anzahl reproduzierter Kontrollwörter unterschied sich zwischen beiden Altersgruppen jedoch nicht (Tabelle 6). Dieser Befund verdeutlicht, dass ältere Erwachsene nicht lediglich aufgrund eines größeren Wortschatzes eine ausgeprägtere Tendenz zum Paraphrasieren aufweisen als jüngere Erwachsene und daher eher das Distraktorwort zur Beschreibung des Textinhaltes verwenden. Die Intrusionen von nicht-assoziierten Distraktoren zeigen zudem, dass Distraktoren zumindest gelegentlich in die mentale Repräsentation der Texte integriert werden und Intrusionsfehler somit nicht nur bei der Rekonstruktion der Geschichte während des Abrufs der mentalen Textrepräsentation aus dem Gedächtnis entstehen (siehe Potter & Lombardi, 1990).

Tabelle 5: Relative Häufigkeit korrekt wiedergegebener Propositionen als Funktion von Gruppe (Spalten) und Distraktorbedingung (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung	Alt
Fließtext	. 27 (. 01)	. 21 (. 01)
Nicht-Assoziierte Distraktoren	. 31 (. 02)	. 17 (. 02)
Assoziierte Distraktoren	. 26 (. 02)	. 14 (. 02)

Tabelle 6: Anzahl von Intrusionen in den Distraktorbedingungen Assoziierte Distraktoren und Nicht-Assoziierte Distraktoren als Funktion von Gruppe (Spalten) und Intrusionsart (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung	Alt
	Intrusionen in Distraktorbedingung Assoziierte Distraktoren	
Assoziierte Distraktoren	4.36 (0.41)	6.09 (0.41)
Kontrollwörter	0.60 (0.15)	0.64 (0.15)
	Intrusionen in Distraktorbedingung Nicht-Assoziierte Distraktoren	
Nicht-Assoziierte Distraktoren	0.47 (0.2)	1.42 (0.2)
Kontrollwörter	0.16 (0.06)	0.10 (0.06)

Experiment 4

Die Ergebnisse von Experiment 3 verdeutlichen, dass Altersunterschiede in der Beeinträchtigung des Textverständnisses dann gemessen werden können, wenn ein Textverständnistest verwendet wird, der zur Erfassung der mentalen Textrepräsentation geeignet ist. Allerdings basiert die Schlussfolgerung, dass ältere Erwachsene von Defiziten in der inhibitorischen Aufmerksamkeitskontrolle betroffen sind, vor allem auf der Analyse der mittleren Lesezeiten für einen gesamten Text. Dieses Prozedere stellt jedoch eine relativ indirekte und daher möglicherweise unpräzise Messung der Interferenzkontrolle dar, denn die Inhibitionsdefizittheorie erlaubt die Ableitung spezifischerer Hypothesen: a) Da ältere Erwachsene die Distraktoren offenbar in die mentale Repräsentation des Zieltextes integrieren, sollte das Lesen der Zieltextwörter bei älteren Erwachsenen in den Experimentalbedingungen stärker verlangsamt sein als bei jüngeren Erwachsenen. b) Unter der Annahme, dass die Lesezeit eines Wortes die Intensität reflektiert, mit der es verarbeitet wird (Just, Carpenter, & Woolley, 1982), sollten ältere Erwachsene vor allem beim Lesen der Distraktorwörter stärker verlangsamt sein als jüngere Erwachsene. In Experiment 4 sollten diese präziseren Hypothesen mit Hilfe der *Moving-Window*-Methode (Soederberg Miller, Stine-Morrow, Kirkorian, & Conroy, 2004; Stine-Morrow, Soederberg Miller, Gagne, & Hertzog, 2008) untersucht werden. Es nahmen 2 Gruppen an dem Experiment teil: 1) jüngere Erwachsene (im Alter von 18 - 30 Jahren) und 2) ältere Erwachsene (im Alter von 60 - 86 Jahren). Um die potentielle Erhöhung der Ablenkbarkeit durch Einbußen in der Sehschärfe zu verhindern, wurde der Visus der jüngeren Erwachsenen ebenso wie in Experiment 3 auf die Sehschärfe eines zufällig ausgewählten älteren Erwachsenen reduziert. Die Materialien, Bedingungen und Abläufe waren identisch zu Experiment 3. Nun wurden die Texte jedoch Wort-für-Wort mit Hilfe der *Moving-Window*-Methode präsentiert. Der Proband ließ sich mittels Tastendruck die einzelnen Wörter nacheinander anzeigen. Währenddessen wurde die räumliche Konfiguration des jeweiligen Textes durch die im Text vorhandenen Satzzeichen, Leerzeichen und durch Bindestrichsequenzen angezeigt, deren Länge den im Text befindlichen Wörtern entsprach. Mit jedem Tastendruck des Probanden wurden die Buchstaben des soeben gelesenen Wortes erneut durch Bindestriche ersetzt, und das nächste Wort erschien stattdessen auf dem Bildschirm. Wie bei der Verwendung der *Moving-Window*-Methode üblich, wurden die Probanden nun angeleitet, die Texte leise und in einer Geschwindigkeit zu lesen, die ein Verständnis der Texte ermöglicht. Wie in Experiment 3 folgte auf jeden gelesenen Text eine freie Reproduktionsaufgabe.

Abbildung 5 illustriert die Ergebnisse der mittleren Lesezeiten für einen gesamten Text, Tabelle 7 führt die Lesezeiten für die einzelnen Wortkategorien auf. Hinsichtlich der Lesezeit für einen gesamten Text zeigte sich erneut, dass ältere Erwachsene in den Experimentalbedingungen stärker verlangsamt waren als jüngere Erwachsene (Abbildung 5).

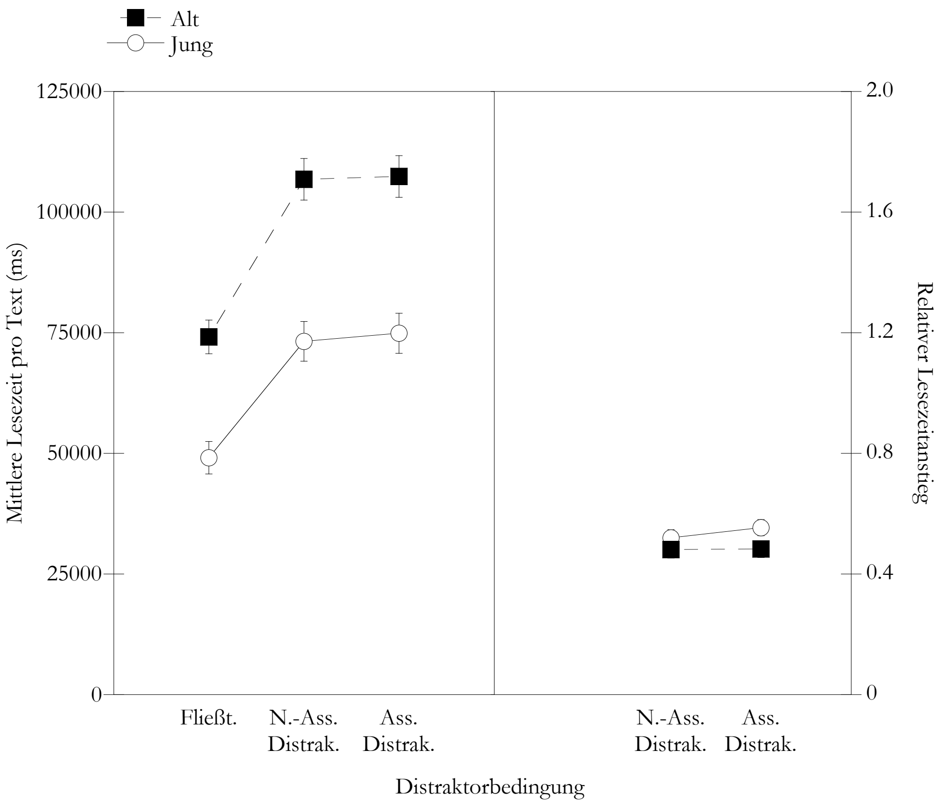

Abbildung 5: Lesezeiten in Experiment 4. Linke Seite: Mittlere Lesezeiten für einen gesamten Text als Funktion von Distraktorbedingung und Gruppe. Rechte Seite: Mittlerer proportionaler Lesezeitanstieg in den Distraktorbedingungen Nicht-Assoziierte Distraktoren (N.-Ass. Distrak.) und Assoziierte Distraktoren (Ass. Distrak.) relativ zu der Distraktorbedingung Fließtext (Fließt.). Die Fehlerbalken kennzeichnen die Standardfehler der Mittelwerte.

In Bezug auf die Lesezeiten für die Zieltextwörter zeigte sich allerdings, dass der Lesezeitanstieg in den Experimentalbedingungen für ältere und für jüngere Erwachsene identisch war (Tabelle 7). Die separate Analyse der Lesezeiten für die Distraktorwörter verdeutlichte darüber hinaus, dass ältere Erwachsene die Distraktoren zwar länger lesen, aber dass dieser Altersunterschied selbst in der Distraktorbedingung Assoziierte Distraktoren (271 ms; ältere Erwachsene lesen 36.4% langsamer als jüngere Erwachsene) kleiner ist als der Altersunterschied, der in der Kontrollbedingung für die Lesezeiten der Zieltextwörter vorliegt (417 ms; ältere Erwachsene lesen 50.9% langsamer als jüngere Erwachsene). Somit scheint in Experiment 4 der altersbezogene Lesezeitanstieg in den Experimentalbedingungen eher auf eine allgemeine kognitive Verlangsamung zurückzuführen zu sein als auf ein spezielles Problem in der Interferenzkontrolle. Diese Annahme wird zusätzlich durch die Auswertung der proportionalen Lesezeiten gestützt (Abbildung 5), in der sich im Gegensatz zu den vorherigen drei Experimenten keine Altersunterschiede in der Lesezeitverlangsamung zeigten.

Tabelle 7: Ergebnisse der separaten Analyse der Lesezeiten für Zieltextwörter und für Distraktorwörter. Angegeben ist die mittlere Lesezeit eines Wortes (in Millisekunden) als Funktion von Gruppe (Spalten), Wortkategorie (Zeilen) und Distraktorbedingung (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung	Alt
	Zieltextwörter	
Fließtext	818.6 (55.9)	1235.8 (58.3)
Nicht-Assoziierte Distraktoren	862.1 (60.0)	1299.0 (62.6)
Assoziierte Distraktoren	876.0 (57.3)	1281.8 (59.8)
	Distraktorwörter	
Nicht-Assoziierte Distraktoren	716.9 (26.4)	962.5 (27.5)
Assoziierte Distraktoren	745.1 (32.4)	1016.5 (33.8)

Tabelle 8 und Tabelle 9 führen die Ergebnisse der freien Reproduktionsaufgabe auf. Die Anzahl reproduzierter Propositionen war bei älteren Erwachsenen in beiden Experimentalbedingungen im Gegensatz zu Experiment 3 nicht reduziert (Tabelle 8). Konsistent zu Experiment 3 unterliefen älteren Erwachsenen hingegen erneut in beiden Experimentalbedingungen mehr Intrusionen von Distraktoren, ohne dass Altersunterschiede in der Anzahl reproduzierter Kontrollwörter auftraten (Tabelle 9).

Tabelle 8: Relative Häufigkeit korrekt wiedergegebener Propositionen als Funktion von Gruppe (Spalten) und Distraktorbedingung (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung	Alt
Fließtext	. 35 (. 02)	. 26 (. 02)
Nicht-Assoziierte Distraktoren	. 36 (. 02)	. 24 (. 02)
Assoziierte Distraktoren	. 37 (. 02)	. 23 (. 02)

Tabelle 9: Anzahl von Intrusionen in den Distraktorbedingungen Assoziierte Distraktoren und Nicht-Assoziierte Distraktoren als Funktion von Gruppe (Spalten) und Intrusionsart (Zeilen). Die Zahlen in Klammern repräsentieren die Standardfehler der Mittelwerte.

	Jung	Alt
	Intrusionen in Distraktorbedingung Assoziierte Distraktoren	
Assoziierte Distraktoren	2.84 (0.36)	4.91 (0.34)
Kontrollwörter	1.80 (0.17)	0.76 (0.16)
	Intrusionen in Distraktorbedingung Nicht-Assoziierte Distraktoren	
Nicht-Assoziierte Distraktoren	0.31 (0.15)	0.91 (0.15)
Kontrollwörter	0.14 (0.05)	0.04 (0.05)

Allgemeine Diskussion

Die in der vorliegenden Arbeit geschilderten Einzelexperimente geben Aufschluss hinsichtlich der Frage, ob die Altersunterschiede beim Lesen mit Distraktoren aus einem altersbedingten Inhibitionsdefizit resultieren. Entgegen der Vorhersagen der Inhibitionsdefizittheorie fanden sich zwar nicht in allen experimentellen Manipulationen Altersunterschiede in der Ablenkbarkeit, so dass der umfassende Geltungsanspruch der Inhibitionsdefizittheorie kritisch betrachtet werden muss. Dennoch sprechen die Befunde vorliegender Arbeit mehrheitlich für eine ausgeprägtere Interferenzanfälligkeit im höheren Lebensalter, so dass die gegenwärtigen Befunde grundsätzlich konsistent sind mit der Annahme, dass altersbedingte Probleme in speziellen Inhibitionsfunktionen existieren.

In den ersten beiden Experimenten sollte überprüft werden, ob die Altersunterschiede in der Ablenkbarkeit beim Lesen mit Distraktoren ausschließlich auf altersbedingte sensorische Defizite zurückzuführen sind. Zwar zeigte sich, dass eine Reduktion der Sehschärfe bei beiden Altersgruppen zu einer Erhöhung der Lesezeitverlangsamung in den Experimentalbedingungen führte. Allerdings ging aus den Daten eindeutig hervor, dass altersbedingte sensorische Einbußen alleine die Altersunterschiede in der Interferenzanfälligkeit beim Lesen mit Distraktoren nicht erklären können. Weder konnte die Interferenzanfälligkeit älterer Erwachsener bei jüngeren Erwachsenen durch eine künstliche Reduktion der Sehschärfe simuliert werden, noch wurden die Altersunterschiede in der Interferenzanfälligkeit aufgehoben oder auch nur verringert, wenn ältere und jüngere Erwachsene über dieselben sensorischen Grundvoraussetzungen hinsichtlich der Sehschärfe verfügten. Darüber hinaus zeigten sich in den übrigen Experimenten ebenfalls Altersunterschiede in der Ablenkbarkeit, obwohl in diesen Experimenten altersbedingte Unterschiede in der Sehschärfe gleichermaßen kontrolliert wurden. Eine mögliche Alternativerklärung für die Befunde beim Lesen mit Distraktoren - dass die Altersunterschiede in der Interferenzanfälligkeit in diesem Paradigma ausschließlich auf altersbedingte sensorische Defizite zurückzuführen sind (Burke & Osborne, 2007; Burke & Shafto, 2008) - kann somit aufgrund der Resultate der vorliegender Arbeit klar zurückgewiesen werden. Die aktuellen Ergebnisse liefern vielmehr deutliche Belege dafür, dass das Befundmuster beim Lesen mit Distraktoren auf altersbedingten Veränderungen in höheren kognitiven Prozessen beruht. Dieses Ergebnis entspricht den Befunden der Arbeit von Lindenberger et al. (2001), in der gleichermaßen kein direkter Einfluss einer künstlichen Sehschärfereduktion auf die Altersunterschiede bei Leistungen in verschiedenen kognitiven Tests nachgewiesen werden konnte. Darüber hinaus zeigten sich Altersunterschiede in der Ablenkbarkeit beispielsweise auch in Paradigmen wie dem *Irrelevant-Sound*-Effekt, in denen Zielreize und Distraktoren in verschiedenen Modalitäten präsentiert werden und altersbedingte sensorische Defizite aufgrund der guten perzeptuellen Unterscheidbarkeit von aufgabenrelevanten und aufgabenirrelevanten Reizen schwerlich für die gefundenen Altersunterschiede verantwortlich sein können (Bell, Buchner, & Mund, 2008). Die Befunde der vorliegenden Arbeit schließen altersbedingte sensorische Defizite nun jedoch auch als Alternativerklärung für das Datenmuster einer Aufgabe aus, die im Gegensatz zu oben aufgeführten Befunden insbesondere die Differenzierung von subtilen perzeptuellen Unterschieden im Schriftbild erfordert. Dennoch erhöhte eine künstliche Reduktion der Sehschärfe beim Lesen mit Distraktoren die Ablenkbarkeit der Probanden. Somit lassen die Befunde der vorliegenden Arbeit erkennen, dass altersbedingte Veränderungen von sensorischen Fähigkeiten in Studien zu Altersunterschieden in kognitiven Leistungen stets sorgfältig kontrolliert werden sollten, um potentielle Überschätzungen der Altersunterschiede in den kognitiven Fähigkeiten ausschließen zu können.

Doch die Vernachlässigung von altersbedingten sensorischen Defiziten stellte nicht den einzigen zu kritisierenden methodischen Aspekt der vorherigen Studien zum Lesen mit Distraktoren dar. So wurde bislang ein Textverständnistest verwendet, der eher die Erinnerung an oberflächliche Merkmale eines Textes erfasst als die mentale Textrepräsentation und der über eine geringe Reliabilität verfügt. Die insgesamt uneinheitliche Befundlage hinsichtlich der Beeinträchtigung des Textverständnisses durch Distraktoren schien prinzipiell jedoch auch mit der Annahme vereinbar, dass keine altersbezogenen Einbußen in der inhibitorischen Aufmerksamkeitskontrolle existieren (Burke, 1997; Burke & Osborne, 2007) und die uneinheitliche Befundlage stattdessen aus dem Zusammenspiel von Alpha-Fehler und Publikationsbias in Richtung Veröffentlichung von (statistisch) „signifikanten" Ergebnissen resultiert. Tatsächlich signalisieren die Befunde des dritten Experiments jedoch, dass die früheren Inkonsistenzen auf den ungünstigen psychometrischen Eigenschaften des Testverfahrens zu beruhen scheinen.

Bei Verwendung einer freien Reproduktionsaufgabe statt eines Rekognitionstests zeigten sich durchaus zahlreiche Hinweise für distraktorinduzierte Interferenzen im Gedächtnis, die bei älteren Erwachsenen stärker ausgeprägt waren als bei jüngeren Erwachsenen. So reproduzierten ältere Erwachsene im Gegensatz zu jüngeren Erwachsenen in den Experimentalbedingungen deutlich weniger Propositionen. Darüber hinaus unterliefen älteren Erwachsenen mehr Intrusionsfehler. Diese Befunde stützen die Annahme eines altersbedingten Inhibitionsdefizits.

Darüber hinaus konnten über alle Experimente hinweg zahlreiche Altersunterschiede in der Interferenzanfälligkeit in verschiedenen abhängigen Variablen aufgezeigt werden. Bei ausreichender Teststärke und bei Verwendung eines geeigneteren Textverständnistest zeigten sich beispielsweise Altersunterschiede in der Anzahl von Intrusionsfehlern in insgesamt drei Experimenten. Sicherlich könnten Intrusionsfehler ebenso aus Defiziten im Quellengedächtnis wie aus einem Inhibitionsdefizit resultieren (Bell et al., 2008; Dywan & Murphy, 1996). In weiteren Arbeiten sollte daher die Bedeutung von altersbedingten Defiziten im Quellengedächtnis (siehe Johnson et al., 1993) für das Entstehen von Intrusionsfehlern beim Lesen mit Distraktoren konkretisiert werden, beispielsweise indem die Erinnerung an das Schriftbild des jeweiligen Wortes (aufrecht oder kursiv) mit einem zusätzlichen Quellengedächtnistest erfasst wird. Neben Intrusionsfehlern zeigten ältere Erwachsene allerdings auch eine überproportionale Lesezeitverlangsamung in den Experimentalbedingungen der ersten drei Experimente. Insgesamt sprechen die Ergebnisse vorliegender Arbeit also für eine intensivere Verarbeitung von aufgabenirrelevanter Information und somit für ein Nachlassen der inhibitorischen Aufmerksamkeitskontrolle im höheren Lebensalter.

Die Überprüfung konkreterer Hypothesen der Inhibitionsdefizittheorie erforderte jedoch weitere methodische Veränderungen wie die Wort-für-Wort Präsentation der Texte sowie die Instruktion, leise und in einer Geschwindigkeit zu lesen, die ein Verständnis der Texte ermöglicht. Bei diesen Modifikationen zeigten sich keine Evidenzen für Altersunterschiede in der Ablenkbarkeit bei der unmittelbaren Verarbeitung der Texte. So fanden sich in den Experimentalbedingungen des vierten Experiments weder eine überproportionale Verlangsamung älterer Erwachsener, noch wurde der Aufbau einer mentalen Textrepräsentation bei älteren Erwachsenen durch die Distraktoren beeinträchtigt. Diese Befunde stehen im klaren Widerspruch zu den eindeutigen Vorhersagen der Inhibitionsdefizittheorie und zu den Ergebnissen der ersten drei Experimente. Da im vierten Experiment mehrere Aspekte simultan an dem Paradigma modifiziert wurden, ist es schwierig, einen einzelnen methodischen Gesichtspunkt als Ursache für die Diskrepanz zu den ersten drei Experimenten zu identifizieren. Dennoch ist interessant, dass die Probanden sowohl im vierten Experiment als auch in anderen Studien, die keine Altersunterschiede in der Interferenzanfälligkeit beim Lesen mit Distraktoren fanden (Kemper & McDowd, 2006; Kemper et al., 2008), die Texte leise lesen sollten. Darüber hinaus zeigte sich in Studien, in denen die Probanden die Texte laut vorlesen sollten, dass ältere Erwachsene die Distraktoren öfter vorlesen als jüngere Erwachsene (Connelly et al., 1991; Dywan & Murphy, 1996). Somit bestehen möglicherweise altersbedingte Probleme in der Unterdrückung des Vorlesens der Distraktoren, die dann zu Beeinträchtigungen bei der unmittelbaren Textverarbeitung führen. Die systematische Untersuchung des Einflusses von Schwierigkeiten in der Unterdrückung der Sprachproduktion auf das Auftreten von Altersunterschieden beim Lesen mit Distraktoren stellt somit einen interessanten Ansatzpunkt für weiterführende empirische Arbeiten dar. Unabhängig von der tatsächlichen Ursache für das Ausbleiben der Altersunterschiede in der Interferenzanfälligkeit verdeutlicht das vierte Experiment jedoch, dass das Auftreten dieser Altersunterschiede während der unmittelbaren Textverarbeitung beim Lesen mit Distraktoren von der konkreten Umsetzung des Paradigmas abhängt. Dieser Sachverhalt ist konsistent mit der Annahme, dass altersbedingte Defizite in spezifischen Inhibitionsfunktionen existieren, ältere Erwachsene jedoch nicht generell eine stärkere Interferenzanfälligkeit aufweisen (Kramer, Humphrey, Larish, & Logan, 1994). Zusätzliche Unterstützung erfährt diese Annahme durch die bereits erörterten Inkonsistenzen in Befunden aus anderen zur Überprüfung der Inhibitionsdefizittheorie herangezogenen Paradigmen wie dem *Negative-Priming*-Effekt (Buchner & Mayr, 2004; Connelly & Hasher, 1993; Kramer & Strayer, 2001) oder dem *Stroop*-Effekt (Verhaeghen & De Meersman, 1998). Darüber hinaus zeigte sich beispielsweise auch bei dem *Irrelevant-Sound*-Effekt, dass das von der Inhibitionsdefizittheorie prognostizierte Entstehen von Altersunterschieden in der Größe des Effektes von der Art des verwendeten Stimulusmaterials und somit auch von der konkreten Umsetzung des Paradigmas abhängt (Bell et al., 2008). Insofern ergänzen die Ergebnisse der vorliegenden Arbeit das Befundmuster in der Literatur zur Interferenzanfälligkeit im höheren Lebensalter, demzufolge einige Inhibitionsfunktionen im höheren Lebensalter weiterhin erhalten zu sein scheinen (Bell & Buchner, 2007; Van Gerven, Meijer, Vermeeren, Vuurman, & Jolles, 2007) während andere Inhibitionsfunktionen Defizite aufweisen (Bell et al., 2008; Titz & Verhaeghen, 2010). Angesichts des derzeitigen Forschungsstandes scheint daher die Erarbeitung spezifischerer Theorien notwendig, die Aussagen darüber treffen, welche Inhibitionsfunktionen unter welchen Umständen mit zunehmendem Alter ineffizienter arbeiten. Allerdings ist fraglich, inwieweit solche spezifischen Defizite der inhibitorischen Aufmerksamkeitskontrolle noch einen Großteil der altersbedingten kognitiven Leistungseinbußen erklären können. Dem umfassenden Geltungsanspruch einer globalen Theorie des kognitiven Alterns kann die Inhibitionsdefizittheorie daher nur schwerlich gerecht werden.

Zusammenfassend lässt sich aufgrund der Befunde vorliegender Arbeit feststellen, dass sich zahlreiche Evidenzen für eine erhöhte Interferenzanfälligkeit älterer Erwachsener beim Lesen mit Distraktoren fanden. Zunächst erwies sich die vorgebrachte Alternativerklärung, dass eine reduzierte Sehschärfe im höheren Lebensalter für das Entstehen der Altersunterschiede beim Lesen mit Distraktoren verantwortlich ist, als empirisch nicht haltbar. Eine künstliche Reduktion der Sehschärfe führte zwar zu einer Erhöhung der alterskorrelierten Lesezeitverlangsamung in den Experimentalbedingungen, altersbedingte sensorische Einbußen konnten die gefundenen Altersunterschiede in der Interferenzanfälligkeit jedoch nicht erklären. Des weiteren zeigten sich unter Verwendung eines geeigneteren Testverfahrens ausgeprägte Altersunterschiede in der Beeinträchtigung des Textverständnisses durch Distraktoren. Somit scheint die inkonsistente Befundlage hinsichtlich der Ergebnisse des bislang verwendeten Rekognitionstests aus den ungünstigen psychometrischen Eigenschaften dieses Testverfahrens zu resultieren. Allerdings finden sich Altersunterschiede in der Interferenzanfälligkeit nicht immer. Ihr Auftreten ist vielmehr abhängig von der konkreten Umsetzung des experimentellen Paradigmas. Diese Tatsache verdeutlicht die Notwendigkeit der Erarbeitung spezifischerer Theorien zur Klärung der Frage, unter welchen Bedingungen und für welche Anforderungen einem altersbedingtem Inhibitionsdefizit eine zentrale Rolle für das Entstehen altersbezogener kognitiver Einbußen zukommt.

Endnoten

[1] Auch die Ergebnisse der ersten beiden Experimente dieser Arbeit (Mund, Bell, & Buchner, in press) werden in Tabelle 1 in Artikel 2 aufgeführt. Da die Beschreibung der Ergebnisse von Experiment 1 und Experiment 2 in dieser Zusammenfassung jedoch erst später erfolgt, werden sie an dieser Stelle noch nicht zu den vorherigen Studien gezählt.

[2] Duchek et al. (1998) berichten ebenfalls eine proportionale Auswertung der Lesezeiten, in der die Altersunterschiede in der Lesezeitverlangsamung sogar bestehen bleiben. Allerdings flossen in diese Analyse die Ergebnisse von Alzheimer-Patienten zusammen mit den Ergebnissen von gesunden älteren Erwachsenen ein, so dass nicht auszuschließen ist, dass die dort aufgezeigte überproportionale Verlangsamung älterer Erwachsener auf pathologischen kognitiven Veränderungen beruht.

[3] Der mittlere proportionale Lesezeitanstieg wurde berechnet, indem die Differenz zwischen der mittleren Lesezeit in der Distraktorbedingung Assoziierte Distraktoren zu der mittleren Lesezeit in der Distraktorbedingung Lücken an der mittleren Lesezeit in der Distraktorbedingung Lücken relativiert wurde: $\frac{LZ_{Assoziierte\ Distraktoren} - LZ_{Lücken}}{LZ_{Lücken}}$. Nach diesem Prinzip erfolgte auch in den übrigen Experimenten die

Berechnung des proportionalen Lesezeitanstiegs mit den jeweils verwendeten Distraktorbedingungen.

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Einzelarbeiten

Experimente 1 und 2

Mund, I., Bell, R., & Buchner, A. (in press). Age differences in reading with distraction: Sensory or inhibitory deficits? *Psychology and Aging.*

Experiment 3

Mund, I., Bell, R., & Buchner, A. (2010). Aging and interference in story recall (manuscript under review).

Experiment 4

Mund, I., Bell, R., & Buchner, A. (2010). Reading with Distraction: Similarities and differences between older and younger adults (manuscript submitted for publication).

Psychology and Aging
© 2010 American Psychological Association
0882-7974/10/$12.00 DOI: 10.1037/a0019508

Age Differences in Reading With Distraction: Sensory or Inhibitory Deficits?

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Two experiments examined how sensory acuity affects age differences in susceptibility to interference in the reading-with-distraction task. In both experiments, older and younger adults read texts in an italic font and were required to ignore distractor words in an upright font. Experiment 1 examined whether the age-related increase in distractibility can be simulated in younger adults by reducing their visual acuity. Experiment 2 investigated whether the age differences in distractibility disappear if visual acuity is equated across all participants in both age groups. Both experiments showed that an impairment in visual acuity leads to increased interference in the reading-with-distraction task. However, older adults were much more impaired by the distractor material than younger adults with reduced visual acuity (Experiment 1). The age differences in the reading-with-distraction task persisted when visual acuity was equated between older and younger adults (Experiment 2). We conclude that the age-related increase in susceptibility to interference in the reading-with-distraction task is not solely due to perceptual deficits of older adults but arises from a deficit in higher cognitive processes such as inhibitory attention. Nevertheless, sensory acuity has to be taken into account as a potential confounding factor in perceptually demanding visual attention tasks.

Keywords: perceptual deficit hypothesis, sensory deficit hypothesis, inhibitory deficit theory, selective attention, cognitive aging

With increasing age, cognitive performance decreases. Evidence for an age-related decline in many cognitive functions such as attention, memory, speech production, and comprehension can easily be found (Light, 2000; McDaniel, Einstein, & Jacoby, 2008; Zacks, Hasher, & Li, 2000). One of the most important theoretical accounts of the cognitive aging phenomenon is the inhibition deficit theory (Hasher & Zacks, 1988). This theory attributes the age-related decline in cognitive functioning to a deficit in inhibitory attention. According to inhibition deficit theory, this deficit has pronounced effects on cognitive performance because inhibitory attention is essential for efficient information processing. More precisely, it has been proposed (Hasher, Zacks, & May, 1999) that inhibitory control is necessary (a) to prevent irrelevant stimuli from entering working memory where they would disrupt processing of relevant information (*access function*); (b) to delete no longer relevant information from working memory (*deletion function*); and (c) to control dominant but inadequate response tendencies (*restraint function*).

The present study deals with age differences in the access function of inhibitory control. With a deficit in this function, processing of irrelevant extraneous information cannot be avoided. This processing of irrelevant material interferes with the processing of relevant information. As a consequence, cognitive performance declines. Consistent with the assumption of an age-related deficit in the access function, a large amount of evidence suggests that older adults are more susceptible to external distraction than younger adults. For instance, older adults are more impaired by meaningful irrelevant background speech when engaged in demanding working memory tasks (Bell, Buchner, & Mund, 2008; Meijer, de Groot, Van Boxtel, Van Gerven, & Jolles, 2006; Tun, O'Kane, & Wingfield, 2002; Tun & Wingfield, 1999).

One of the most important empirical findings that support the hypothesis of an age-related deficit in the access function of inhibitory control is that older adults are more impaired by distractor words when reading. This finding is frequently cited in cognitive psychology handbooks and textbooks (Hasher, Lustig, & Zacks, 2007; Lustig & Hasher, 2001; Lustig, Hasher, & Zacks, 2007; Zacks & Hasher, 1994; Zacks et al., 2000). The reading-with-distraction task was introduced by Connelly, Hasher, and Zacks (1991). In the original version of this task, participants were required to read aloud short texts. In the distractor words condition, to-be-ignored words in a distinct font style (upright font) were interspersed among the to-be-read text (displayed in an italic font). Connelly et al. (1991) found that the increase in reading time in the distractor words condition relative to the control condition was larger for older adults than for younger adults. These age differences in distractibility were most pronounced when the distractor words were semantically related to the target text. In a subsequent multiple-choice text comprehension test, participants were required to identify previously read target words among new and previously ignored distractor words. Consistent with inhibition deficit theory, older adults made more intrusion errors (i.e., chose the previously to-be-ignored distractor word instead of the target word more often) than younger adults. Age differences in the susceptibility to interference in the reading-with-distraction paradigm have been replicated in several subsequent experiments (Carlson, Hasher, Connelly, & Zacks, 1995; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Duchek, Balota, & Thessing, 1998; Dywan & Murphy, 1996; Kim,

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We thank Martina Bruns and the staff of Die Brille, Krefeld, Germany, for their help.

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Hasher, & Zacks, 2007; Li, Hasher, Jonas, Rahhal, & May, 1998). These results are commonly taken as evidence for a decline in inhibitory efficiency in old age.

However, there might be an alternative explanation for the age differences in the reading-with-distraction task that was neglected in all aforementioned studies. The reading-with-distraction task requires discrimination of subtle perceptual differences between target and distractor font styles. It is plausible that interference in this task increases when target words in an italic font and distractor words in an upright font cannot be discriminated at a perceptual level. Therefore, age differences in the reading-with-distraction task may be caused by a sensory deficit rather than by a deficit in inhibitory attentional control. It is well documented that normal aging is accompanied by a number of changes in the visual system that decrease visual acuity (Fozard, 1990; Schieber, 1992). For instance, aging of the visual system is associated with irregularity of the cornea's surface, opacity of the lenses, senile miosis, thinning of the retinal pigment epithelium, loss of receptor cells, atrophy of retinal ganglion cells, and loss of neurons in the visual cortex. It is important to note that these age-related changes in the visual system cannot be easily compensated by corrective lenses. Thus, a pronounced decrement in the functioning of the visual system can be expected even in samples of older adults with normal cognitive functioning (Schneider & Pichora-Fuller, 2000).

There is ample research showing that sensory and cognitive abilities are correlated (e.g., Clay et al., 2009; Gilmore, Spinks, & Thomas, 2006; Lindenberger, Scherer, & Baltes, 2001). These correlations do not necessarily imply that sensory impairment directly impairs performance in cognitive tests. For instance, both sensory and cognitive deficits may be attributed to common causes, such as age-related biological changes in the brain or health factors, and there is considerable evidence for such indirect links between sensory and cognitive capabilities (e.g., Lindenberger et al., 2001). Nevertheless, a number of researchers argue that impairments in sensory capabilities have direct effects on performance in cognitive tests (e.g., Anstey, Butterworth, Borzycki, & Andrews, 2006; Glass, 2007; Gussekloo, de Craen, Oduber, van Boxtel, & Westendorp, 2005; Valentijn et al., 2005). Most plausibly, sensory impairment may only exert a strong influence on performance in tests that place high demands on sensory processing, such as perceptually demanding selective attention tasks (Schneider & Pichora-Fuller, 2000; Scialfa, 2002). In studies examining auditory selective attention, age differences in auditory distraction disappear when age differences in hearing are controlled for by adjusting the signal-to-noise ratio to the individual hearing threshold (Murphy, Craik, Li, & Schneider, 2000; Murphy, McDowd, & Wilcox, 1999; Schneider, Daneman, Murphy, & See, 2000; Schneider, Daneman, & Pichora-Fuller, 2002).

Schneider and Pichora Fuller (2000) argued that the failure to take age differences in sensory acuity into account may be a problem of studies examining age differences in visual selective-attention tasks. In contrast to studies examining age differences in auditory distraction, studies that have examined age differences in visual attention commonly ignore the problem of age differences in visual acuity possibly amplifying interference effects. The studies using the reading-with-distraction task referred to above are a good example. Given that (a) performance in the reading-with-distraction task most plausibly depends on successful perceptual discrimination of subtly different target and distractor words, and (b) poor visual acuity is prevalent among older adults, one might expect that visual acuity was carefully controlled in studies examining age differences in inhibitory functioning using the reading-with-distraction task. However, none of the published studies we know of (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Duchek et al., 1998; Dywan & Murphy, 1996; Feyereisen & Charlot, 2008; Kemper & McDowd, 2006; Kemper, McDowd, Metcalf, & Liu, 2008; Kim et al., 2007; Li et al., 1998; Phillips & Lesperance, 2003) even reported visual acuity for the older and younger samples.

Thus, it is conceivable that visual acuity has a direct influence on age differences in the reading-with-distraction task. Older adults may, at least occasionally, fail to see the difference between italicized target words and upright distractor words and may therefore process the to-be-ignored distractor words with a higher probability than younger adults. This explanation is consistent with several findings showing that the age differences in the reading-with-distraction task decrease when target and distractor words are perceptually more distinct and can therefore be distinguished more easily, even with reduced visual acuity. For instance, several studies have found no age differences in distractibility when target and distractor words were written in a distinct font color, as a result of which target–distractor discrimination may have been greatly facilitated even with reduced visual acuity (Kemper & McDowd, 2006; Phillips & Lesperance, 2003). Furthermore, when distractor words are presented in predictable locations, age differences in distractibility are severely reduced (Li et al., 1998) or even disappear completely (Carlson et al., 1995). These results have been interpreted within the inhibitory deficit theory. It has been suggested that inhibition of locations may be preserved in old age. However, an alternative interpretation of these results would be that age differences are reduced or eliminated because target and distractor words that are presented in different locations can be distinguished more easily at a perceptual level, even with reduced visual acuity. Thus, almost all age differences in the reading-with-distraction task could be attributed either to age differences in inhibitory control or to age differences in visual acuity. Given this, it may be not too surprising that it has been suggested several times that an age-related deficit in inhibitory control does not in fact exist and that the age differences in the reading-with-distraction task can be solely attributed to sensory decline (Bell & Buchner, 2007; Bell et al., 2008; Burke & Osborne, 2007; Burke & Shafto, 2008). We henceforth refer to this hypothesis as the *sensory-deficit* hypothesis.[1] Consistent with the sensory-deficit hypothesis, Gra-

[1] At first glance, the sensory-deficit hypothesis might seem inconsistent with the findings of Kemper and McDowd (2006), who used eye tracking technology to examine age differences in a modified reading-with-distraction task and found no age differences in the probability of fixating distractors. However, this null finding cannot rule out the sensory-deficit hypothesis, because Kemper and McDowd used a modified reading-with-distraction paradigm (e.g., participants read only single sentences, which may have drastically reduced the task's sensitivity to age differences) in which there was no evidence for age differences in interference at all. With no evidence of age-related interference at a performance level, there is also no reason why the probability of distractor fixations should have differed between age groups. An additional problem with this study is that the hypothesis that older adults should fixate distractors more often than younger adults can be derived equally well from the inhibitory-deficit hypothesis and from the sensory-deficit hypothesis. Therefore, no conclusions can be drawn from these findings about whether the age differences in the classical version of the reading-with-distraction task can be attributed to sensory decline.

ham, Osborne, and Burke (2007) reported a significant correlation between visual acuity and distractibility in the reading-with-distraction task. Note, however, that a significant correlation between visual acuity and distractibility could be due to indirect links between sensory and cognitive capabilities. Thus, to examine whether visual functioning has a direct effect on interference in the reading-with-distraction task, it is necessary to manipulate visual acuity experimentally.

In Experiment 1 we examined whether age effects in the reading-with-distraction task can be simulated in younger adults by reducing their visual acuity to that of older adults. To simulate the age-related decline of visual acuity, we used glasses with partial occlusion filters that are commonly used in strabismus monocularis and amblyopia treatment to selectively reduce visual acuity of the better seeing eye (Haase & Gräf, 2003). These partial occlusion filters reduce visual acuity by light scattering. Lindenberger et al. (2001) used this method to examine direct influences of sensory acuity on cognitive functioning. In their study, younger adults with reduced visual acuity and younger control participants completed a cognitive test battery designed to assess working memory, perceptual speed, reasoning, episodic memory, verbal knowledge, and verbal fluency. Visual acuity had no direct effect on any of these functions. Lindenberger et al. concluded that the link between sensory and cognitive decline is most plausibly due to a common biological process that may affect both sensory and cognitive capabilities. However, even though this may be true for the tasks that were used by Lindenberger et al., it is unclear whether visual acuity directly affects distractibility in perceptually demanding visual selective-attention paradigms, such as the reading-with-distraction task (Scialfa, 2002).

To summarize, the sensory-deficit hypothesis (Burke & Osborne, 2007) implies that age differences in the reading-with-distraction task are solely due to a sensory deficit that leads to poor perceptual discrimination between target and distractor words. Therefore, this hypothesis leads to the prediction that age-related deficits in the reading-with-distraction task can be simulated by artificially reducing visual acuity of younger adults. The inhibitory-deficit hypothesis (Hasher et al., 2007), in contrast, implies that age differences in the reading-with-distraction task are solely due to insufficient inhibitory control over the contents of working memory. According to this view, perceptual deficits do not play a role in amplifying age differences in distractibility. Therefore, this hypothesis leads to the prediction that visual acuity reduction does not affect distractibility in the reading-with-distraction task.

Experiment 1

Method

Participants. Participants were 50 community-dwelling older adults and 92 younger adults. Two participants (one older and one younger adult) were excluded on the basis of the results of a dementia screening test. The remaining 49 older adults (34 women) ranged in age from 60 to 83 years ($M = 68.10$, $SD = 5.75$). The remaining 91 younger adults (67 women) ranged in age from 19 to 30 years ($M = 22.88$, $SD = 3.35$). The latter were randomly assigned to two groups (the visual acuity reduction group and the control group; see below). All participants were native German speakers. Younger adults had more years of education than older adults, $F(1, 138) = 25.20$, $p < .01$, $\eta^2 = .15$. However, older adults performed better on a vocabulary test (Lehrl, 1989) than younger adults, $F(1, 138) = 7.95$, $p < .01$, $\eta^2 = .05$. The scores in the dementia screening test (DemTect; Kalbe et al., 2004) did not differ between age groups, $F(1, 138) = 1.06$, $p = .31$, $\eta^2 = .01$. Participants with a diagnosis of mild cognitive impairment in the dementia screening, those with a history of heart attack, stroke, brain trauma, alcoholism, Parkinson's disease, or pulmonary emphysema, and those who had taken medication that could influence their cognitive functioning were excluded from the study. Older and younger adults did not differ with respect to their self-assessed overall contentment with life, $\chi^2(1, N = 140) = 0.43$, $p = .51$.

Sensory acuity manipulation. To simulate the age-related decline of visual acuity, we required participants in the younger, visual acuity reduction group to wear glasses with thin, self-adhesive partial occlusion filters (Ryser Optik, St. Gallen, Switzerland). There are several types of partial occlusion filters that reduce visual acuity to different degrees. These filters are labeled according to the degree of visual acuity that will result if they are used by an individual with normal or corrected-to-normal visual acuity of 1.0. As in Lindenberger et al.'s (2001) study, partial occlusion filters labeled 0.4 were used in the present study. This means that these filters are expected to reduce visual acuity to values around 0.4 Snellen decimals (Bach, 2007). According to Lindenberger et al., this level of visual acuity most likely corresponds to the age-related sensory decline that is to be expected in a sample of elderly people. Besides, a further advantage of using partial occlusion filters labeled 0.4 is that Lindenberger et al. have shown that this degree of acuity reduction does not result in impairments of higher cognitive functions (including perceptual speed, memory, reasoning and knowledge). Thus, if performance in the reading-with-distraction task would be modulated by the visual acuity reduction, these effects would most likely not be mediated by a depletion of attentional resources but would rather be due to direct sensory effects on the reading-with-distraction task.

Materials. Visual acuity was tested using a Snellen chart (UNI EN ISO 8596/7). The DemTect was applied as a cognitive screening test to detect dementia or mild cognitive impairment (Kalbe et al., 2004). Crystallized intelligence was assessed using the *Mehrfachwahl-Wortschatz-Intelligenztest* (Multiple-Choice Vocabulary Test; Lehrl, 1989).

During the experiment, participants were seated in front of a 20-in. (50.8-cm) computer monitor. Head position was stabilized with a chin rest and a forehead rest at a viewing distance of 40 cm. Thirteen dictation texts were selected from school books used in seventh or eighth grade. On average, the texts consisted of nine sentences ($SD = 2$) and 120 words ($SD = 2$). As in previous studies (Connelly et al., 1991; Kim et al., 2007), the to-be-read texts were presented in 15-point black italic Courier font on a white background. At the viewing distance of 40 cm, each character subtended about 0.29° vertically and 0.21° horizontally.

For five nouns of each text, two similar nouns were selected that could replace these nouns without changing the meaning of the text. One of these three alternatives was randomly selected to be used as an italicized target word that appeared at the correct position in the text. The other two alternatives were randomly selected to serve as the distractor word (in the distractor words condition) or as a new foil in the multiple-choice recognition test that followed each reading phase (see the Procedures section, below).

Six of the texts were randomly assigned to the distractor words condition on an individual basis. The other 6 texts were assigned to the gap control condition. In the distractor words condition, 50 distractor words (the five unique distractor words repeated 10 times) written in an upright font were randomly interspersed into the target text with the constraint that the distractor word was never the first or the last word of the text, and no distractor word followed another distractor word directly. In the gap control condition, the distractor words were written in white type on a white background so that the participants could not see them.

Procedure. Participants were tested individually. Their task was to read out loud the texts presented on the computer screen in front of them. Two short sentences—one comprising irrelevant distractor words and one comprising no distractor words—were presented to familiarize the participants with the task. In a practice trial, participants read a complete text without distractor words. The practice trial was followed by the 12 experimental trials. Each trial started with a countdown that alerted the participants that a text was about to be presented. Following the offset of the countdown, the text appeared at the center of the screen. Participants knew that they were to read the italicized text out loud as fast as possible without making pauses and without making errors. They had to ignore all words printed in upright font. The texts were presented in random order. When participants had read the last word of the text, the experimenter pressed a key on the computer keyboard to record reading time.

Each text was followed by a recognition test. The recognition test consisted of five three-alternative forced-choice (3-AFC) questions presented one after another. These questions consisted of segments of the sentences comprising one of the five target words selected for presentation in the reading phase that had been replaced by three question marks. The target word, the distractor word, and the foil were presented below the question, and participants were required to name the target word. When all five questions had been answered, the next reading trial was initiated.

Design. A 3×2 design was used with group (younger control vs. younger, visual acuity reduction vs. older control) as between-subjects factor and distractor condition (gap control vs. distractor words) as within-subject factor. The dependent variables were reading time, the proportion of correctly identified targets, and the proportion of intrusion errors in the 3-AFC recognition test. Given a sample size of 140 (with $N = 47$ younger and $N = 49$ older adults in the control groups and $N = 44$ younger adults in the visual acuity reduction group), an effect of size $f = 0.34$ (i.e., between a medium, $f = 0.25$, and a large, $f = 0.40$, effect as defined by Cohen, 1988) could be detected for the interaction between group and distractor condition with a probability of $1 - \beta = .95$ (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007).

Results

Treatment check of the visual acuity manipulation. As was to be expected, visual acuity was worse for older control participants ($Mdn = 0.60$) than for younger control participants ($Mdn = 0.90$), as revealed by a U test ($z = -6.52$, $p < .01$). This is in line with the literature (Fozard, 1990; Schieber, 1992) suggesting that there are several age-related changes in the visual system that cannot be easily compensated with contact lenses or glasses (Schneider & Pichora-Fuller, 2000). Given that a healthy sample of older adults was examined in the present experiment, there is no reason to suspect that age differences in visual functioning were more pronounced in the present study than in previous studies in which no measurements of visual functioning were reported (Carlson et al., 1995; Connelly et al., 1991; Duchek et al., 1998; Dywan & Murphy, 1996; Kemper & McDowd, 2006; Kemper et al., 2008; Kim et al., 2007; Li et al., 1998). The most important question was whether the age differences in visual acuity would disappear when the older control adults were compared with younger adults with visual acuity reduction. It is important to note that visual acuity was even worse for younger adults with visual acuity reduction ($Mdn = 0.40$) than for older control adults ($Mdn = 0.60$, $z = -5.87$, $p < .01$). Thus, if the age differences in the reading-with-distraction task were solely due to sensory decline (as suggested by Burke & Osborne, 2007), we would expect younger adults with visual acuity reduction to be as susceptible as, or even more susceptible than, the older adults to interference in this task.

Reading times. A 3×2 multivariate analysis of variance (MANOVA) with group (younger control vs. younger, visual acuity reduction vs. older control) and distractor condition (gap control vs. distractor words) as independent variables revealed a significant main effect of group, $F(2, 137) = 50.46$, $p < .01$, $\eta^2 = .42$, on reading time (see Figure 1, left panel). Orthogonal contrasts showed that younger adults with visual acuity reduction read more slowly than younger control adults, $F(1, 138) = 8.81$, $p < .01$, $\eta^2 = .06$, and older adults read more slowly than younger adults, $F(1, 138) = 90.95$, $p < .01$, $\eta^2 = .40$. The main effect of distractor condition was also significant, $F(1, 137) = 651.94$, $p < .01$, $\eta^2 = .83$, due to the fact that reading time was larger in the distractor words condition than in the gap control condition.

Most importantly, there was a significant Group $\times$ Distractor Condition interaction, $F(2, 137) = 26.81$, $p < .01$, $\eta^2 = .28$. To further examine this interaction, three separate 2×2 MANOVAs were conducted. First, we compared the younger control group to the older control group to see whether we could replicate the age-related increase in susceptibility to distraction that was observed in previous studies (e.g., Connelly et al., 1991; Duchek et al., 1998; Dywan & Murphy, 1996; Kim et al., 2007; Li et al., 1998). Indeed, older adults were more prone to distraction than younger adults, $F(1, 94) = 38.97$, $p < .01$, $\eta^2 = .29$.

The most interesting question was whether the age-related increase in susceptibility to distraction could also be replicated if we compared older adults to younger adults with visual acuity reduction or whether this pattern would be abolished or even reversed. The analysis showed that the increase in reading times in the distractor words condition compared with the gap control condition was more pronounced for older adults than for younger adults with visual acuity reduction, $F(1, 91) = 16.49$, $p < .01$, $\eta^2 = .15$, although the effect size for the Age Group $\times$ Distractor Condition interaction was somewhat reduced when compared to the preceding analysis. We therefore conclude that sensory differences cannot fully account for the age-related differences in the reading-with-distraction task.

To see whether the sensory manipulation had any influence on the susceptibility to distraction in the reading-with-distraction task,

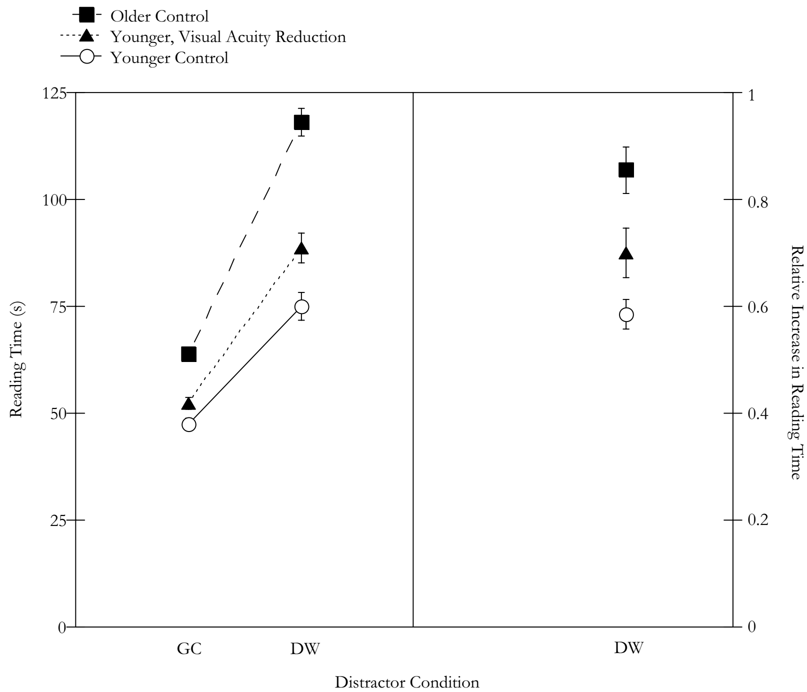

Figure 1. Reading times in Experiment 1. Left panel: Mean reading time as a function of distractor condition (GC = gap control; DW = distractor words) and group. Right panel: Mean proportional increase in reading time in the distractor words condition relative to the gap control condition: $\frac{RT_{\mathrm{DW}} - RT_{\mathrm{GC}}}{RT_{\mathrm{GC}}}$. The error bars represent the standard error of the means.

we compared the younger participants with visual acuity reduction to younger control participants. This analysis revealed a significant interaction between sensory acuity group and distractor condition, $F(1, 89) = 17.78$, $p < .01$, $\eta^2 = .17$. Thus, although sensory decline cannot fully account for the age differences in the susceptibility to interference in the reading-with-distraction task, visual acuity reduction increases distractibility significantly.

To test whether the age differences in reading time were simply due to cognitive slowing, we performed an additional analysis (Duchek et al., 1998; Kim et al., 2007) in which we examined the proportional increase in reading time in the distractor words condition relative to the gap control condition (see Figure 1, right panel), which was calculated by dividing the reading time difference between the distractor words condition ($\mathrm{RT_{DW}}$) and the gap control condition ($\mathrm{RT_{GC}}$) by the reading time in the gap control baseline condition:

$$\frac{RT_{\mathrm{DW}} - RT_{\mathrm{GC}}}{RT_{\mathrm{GC}}}.$$

All conclusions derived from the analysis of the absolute reading times reported above were confirmed. Most important, the relative increase in reading time was larger for older participants than for younger participants in the visual acuity reduction group, $F(1, 91) = 6.03$, $p = .02$, $\eta^2 = .06$, suggesting that cognitive slowing alone cannot fully account for the age-related differences in distractibility (cf. Duchek et al., 1998; Kim et al., 2007).

Recognition test performance. An analysis of the proportion of correctly identified target words in the 3-AFC recognition test (see Table 1) revealed main effects of group, $F(2, 137) = 39.77$, $p < .01$, $\eta^2 = .37$, and of distractor condition, $F(1, 137) = 167.90$, $p < .01$, $\eta^2 = .55$. Orthogonal contrasts showed that older adults correctly identified fewer target words than younger adults, $F(1, 138) = 78.43$, $p < .01$, $\eta^2 = .36$, and that younger adults with visual acuity reduction identified as many target words as younger control participants, $F(1, 138) = 1.52$, $p = .22$, $\eta^2 < .01$. In all three groups, participants correctly identified the target word less often in the distractor words condition than in the gap control condition. Most important, there was no significant interaction between group and distractor condition, $F(2, 137) = 0.67$, $p = .51$, $\eta^2 = .01$.

We also analyzed the error patterns in the distractor words condition. The probability of incorrectly selecting the distractor word was compared to the probability of incorrectly selecting a new foil word that had not been presented in the reading phase (see Table 2). The 3 × 2 MANOVA with group (younger control vs. younger, reduced visual acuity vs. older control) and error type (distractor word vs. new foil word) as independent variables revealed a main effect of group, $F(2, 137) = 20.02$, $p < .01$, $\eta^2 = .23$, suggesting that older adults made more errors than younger adults, $F(1, 138) = 40.03$, $p < .01$, $\eta^2 = .22$, and a main effect of error type (suggesting that participants selected the previously presented distractor word more often than the new foil word), $F(1, 137) = 429.22$, $p < .01$, $\eta^2 = .76$. Most important, there was no interaction between group and error type, $F(2, 137) = 0.83$, $p = .44$, $\eta^2 = .01$, which suggests that intrusions by the distractor material did not differ between the groups. This is consistent with

Table 1
Proportion of Correctly Chosen Target Words (Absolute Number of Correctly Chosen Target Words Divided by Number of Trials) as a Function of Group and Distractor Condition

	Group			
Distractor condition	Younger control	Younger, visual acuity reduction	Older control	Older, visual acuity reduction
Experiment 1				
Gap control	.71 (.01)	.74 (.01)	.61 (.01)	
Distractor words	.58 (.02)	.59 (.02)	.46 (.02)	
Experiment 2				
Continuous control	.82 (.02)	.81 (.02)	.67 (.02)	.67 (.02)
Gap control	.78 (.02)	.82 (.02)	.70 (.02)	.69 (.02)
Random control	.82 (.02)	.85 (.02)	.71 (.02)	.71 (.02)
Distractor words	.58 (.02)	.59 (.02)	.44 (.02)	.40 (.02)

Note. Numbers in parentheses represent the standard error of the mean.

most studies examining age differences in the reading-with-distraction task (Carlson et al., 1995; Connelly et al., 1991; Duchek et al., 1998; Dywan & Murphy, 1996; Kemper & McDowd, 2006; Li et al., 1998; Phillips & Lesperance, 2003).

Discussion

Experiment 1 showed that an artificial decrease of younger adults' visual acuity increased distractibility in the reading-with-distraction task. Thus, age differences in susceptibility to interference may reflect—in part—age differences in sensory capabilities. However, the increase in interference due to the sensory acuity manipulation was much less pronounced than the increase in interference due to cognitive aging. In other words, the age effects in the reading-with-distraction task cannot be fully simulated in younger adults by reducing their visual acuity. This was true even though visual acuity was even worse for younger adults with visual acuity reduction than for older adults. Therefore, we conclude that the sensory-deficit hypothesis is partly correct but cannot fully account for the age differences in the reading-with-distraction task.

In Experiment 1, we examined the sensory-deficit hypothesis by reducing younger adult's visual acuity drastically. This was done to guarantee the comparability between the present study and that of Lindenberger et al. (2001). According to Lindenberger et al., a visual acuity of 0.4 Snellen decimals is commonly observed in a sample of healthy older people. However, using a single value for acuity reduction usually does not result in an exact match for the vision between older and younger adults. In Experiment 2, we thus went one step further and equated visual acuity for two subgroups of younger and older participants by reducing acuity of all of these participants to the same level. In that way, all possible age differences in visual acuity between these two age groups were abolished. The sensory-deficit hypothesis (Burke & Osborne, 2007) leads to the prediction that age differences in distractibility disappear when visual acuity is equal in both age groups. In contrast, the inhibitory-deficit hypothesis (Connelly et al., 1991) again leads to the prediction that the sensory acuity manipulation has no effect on the reading-with-distraction task at all. We also introduced two additional control conditions to allow for a more fine-grained analysis of the age differences in the reading-with-distraction task. First, we used a continuous control condition to assess the "true" baseline in reading speed of the groups involved in this experiment. We also included a random control condition in which random letter strings were interspersed into the text. This condition was designed to assess the extent to which the slowing of the reading speed is caused by lexical and semantic interference. This is possible because differences between the distractor words and

Table 2
Proportion of Errors (Absolute Number of Errors Divided by Number of Trials) in the Distractor Words Condition as a Function of Group and Error Type

	Group			
Error type	Younger control	Younger, visual acuity reduction	Older control	Older, visual acuity reduction
Experiment 1				
Distractors	.32 (.02)	.32 (.02)	.40 (.02)	
New foil words	.10 (.01)	.09 (.01)	.14 (.01)	
Experiment 2				
Distractors	.37 (.02)	.37 (.02)	.47 (.02)	.52 (.02)
New foil words	.05 (.01)	.04 (.01)	.09 (.01)	.08 (.01)

Note. Numbers in parentheses represent the standard error of the mean.

the random control conditions can be assumed to largely reflect the effects of lexical and semantic processes.

Experiment 2

Method

Participants. Seventy-six community-dwelling older adults and 83 younger adults were randomly assigned to two groups. Half of the participants in each age group conducted the experiment with their normal or corrected-to-normal visual acuity. The randomly selected other half of each age group conducted the experiment with their visual acuity artificially reduced to 0.4 to 0.6 Snellen decimals (see the Sensory acuity manipulation section, below). Two participants (one older and one younger adult) were excluded on the basis of the dementia screening. The remaining 75 older adults (55 women) ranged in age from 60 to 85 years (M = 69.64, SD = 4.91). The remaining 82 younger adults (70 women) ranged in age from 19 to 30 years (M = 23.04, SD = 3.13).

All participants were native German speakers. The exclusion criteria were the same as in Experiment 1. None of the participants had taken part in the first experiment. As in Experiment 1, younger adults had more years of education than older adults, $F(1, 155) = 27.45$, $p < .01$, $\eta^2 = .15$, but older adults performed better on the vocabulary test, $F(1, 155) = 42.23$, $p < .01$, $\eta^2 = .21$. Older adults had worse scores in the dementia screening test (DemTect) than younger adults, $F(1, 155) = 7.48$, $p = .01$, $\eta^2 = .05$, but the mean score of older adults (16.79 points) was well within the range of age-appropriate functioning (13 to 18 points). Older and younger adults did not differ with respect to their overall contentment with life, $\chi^2(1, N = 157) < 0.01$, $p = .95$.

Sensory acuity manipulation. To equate visual acuity between younger and older adults in the visual acuity reduction groups, partial occlusion filters were used as in Experiment 1. However, to reduce each participant's visual acuity to between 0.4 and 0.6 Snellen decimals, we used different types of partial occlusion filters that reduced visual acuity to different degrees, depending on the participant's sensory capability. To determine which partial occlusion filter would be necessary to reduce the participant's visual acuity to about 0.4 Snellen decimals, participants were required to judge the orientation of the gap in a Landolt C (Bach, 1996) of 2.5 arc min, which is the smallest gap size that can be reliably detected with a visual acuity of 0.4. The Landolt C was presented on the same computer screen that was used for the experiment proper. At the start of the sensory acuity adjustment procedure, participants wore 0.1 partial occlusion filters (which cause the highest possible degree of visual acuity reduction). If they were unable to identify the orientation of the gap six times in a row, the next weakest partial occlusion filter (0.2) was applied. This procedure continued until the orientation of the gap was correctly identified in six successive trials. The occlusion filter the participants were wearing during these six successive trials was used for visual acuity reduction in the experiment proper.

Materials and procedure. Materials and procedure were identical to those of Experiment 1, with the following exceptions. To assess visual acuity, we used the FrACT (Bach, 2007), a computerized visual screening test. The FrACT was applied before and after the visual acuity adjustment as well as at the end of the experiment. The results of the second visual screening (after visual acuity was adjusted in the visual acuity reduction groups) are displayed in Figure 2. Note that the use of a computerized visual screening test allowed us to assess visual acuity using the same computer monitor that was also used for the visual acuity adjustment and the experiment proper. During the entire experiment (including visual acuity adjustment and assessment), participants had a viewing distance of 110 cm to the computer screen. This distance to the screen was necessary to measure visual acuity up to 1.12 Snellen decimals in the FrACT.

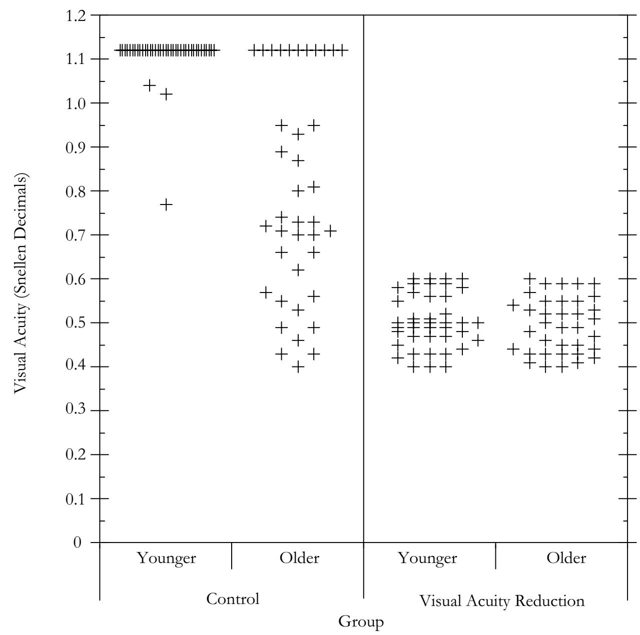

Figure 2. Visual acuity in Snellen decimals for the four groups. Each marker represents the visual acuity of one participant.

For the reading-with-distraction task, 21 dictation texts were selected from school books used in seventh or eighth grade, each containing 60 words. On average, the texts comprised five sentences (SD = 1). Font size was 30 point. At the viewing distance of 110 cm, each character subtended about 0.29° vertically and 0.21° horizontally, which corresponds to the angular size of the characters used in Experiment 1.

For three nouns of each text, two similar nouns were selected that could replace those nouns without changing the meaning of the text. One of these three alternatives was randomly selected to be used as an italicized target word that appeared at the correct position in the text. The other two alternatives were randomly selected to be used as distractor words (in the distractor words condition) or as new foil words in the multiple-choice recognition test that followed each reading phase.

Five texts were randomly assigned to one of four conditions (continuous control, gap control, random control, distractor words) on an individual basis. In the distractor words condition, 30 distractor words (the three unique distractor words repeated 10 times) written in an upright font were interspersed into the texts. In the random control condition, the distractor words were replaced by random letter strings written in an upright font that were of the same length as the distractor words. The gap control condition corresponded to the gap control condition used in Experiment 1. In the continuous control condition, the to-be-read texts were written continuously without distractor words.

Design. A 2 × 2 × 4 design was used with age group (younger vs. older) and sensory acuity group (control vs. visual acuity reduction) as between-subjects factors and distractor condition (continuous control vs. gap control vs. random control vs. distractor words) as within-subject factor. The dependent variables were reading time, the proportion of correctly identified targets, and the proportion of intrusions in the 3-AFC recognition test. Given a sample size of 157 (with $N = 41$ younger and $N = 39$ older adults in the control groups and $N = 41$ younger and $N = 36$ older adults in the visual acuity reduction groups), an effect size of $f = 0.34$ could be detected for the interaction between sensory acuity group and distractor condition with a probability of $1 - \beta = .95$ (Faul et al., 2007, 2009).

Results

Treatment check of the visual acuity manipulation. In the control groups, visual acuity was worse for older ($Mdn = 0.70$) than for younger adults ($Mdn = 1.12$; $z = -6.32$, $p < .01$). In the visual acuity reduction groups, visual acuity was similarly worse for older adults ($Mdn = 0.77$) than for younger adults ($Mdn = 1.12$) when tested without partial occlusion filters ($z = -6.99$, $p < .01$). When tested with partial occlusion filters, visual acuity was the same for older ($Mdn = 0.50$) and younger adults ($Mdn = 0.50$; $z = -0.61$, $p = .54$; see Figure 2). These results confirm that we succeeded in equating visual acuity between older and younger adults with visual acuity reduction. Thus, any differences in distractibility between these two age groups cannot be attributed to differences in visual acuity.

Reading times. A 2 × 2 × 4 MANOVA with age group (younger vs. older), sensory acuity group (control vs. visual acuity reduction), and distractor condition (continuous control vs. gap control vs. random control vs. distractor words) as independent variables revealed significant main effects of age group, $F(1, 153) = 38.00$, $p < .01$, $\eta^2 = .20$; sensory acuity group, $F(1, 153) = 55.13$, $p < .01$, $\eta^2 = .27$; and distractor condition, $F(3, 151) = 278.34$, $p < .01$, $\eta^2 = .85$ (see Figure 3). The main effects of age group and sensory acuity group can be attributed to older adults reading more slowly than younger adults and participants with visual acuity reduction reading more slowly than control participants. Orthogonal contrasts on the distractor condition variable showed that (a) reading times in the gap control condition were slightly increased in comparison to the continuous control condition, $F(1, 153) = 57.10$, $p < .01$, $\eta^2 = .27$; (b) when random letter strings were interspersed into the text, participants read more slowly than when the text contained no distractors, $F(1, 153) = 626.51$, $p < .01$, $\eta^2 = .80$; and (c) reading times in the distractor words condition were increased compared with the control conditions, $F(1, 153) = 451.31$, $p < .01$, $\eta^2 = .75$.

Replicating previous results, there was a significant Age Group × Distractor Condition interaction, $F(3, 151) = 14.21$, $p < .01$, $\eta^2 = .22$, suggesting that older adults were more susceptible to interference than younger adults. The interaction was primarily due to the fact that the increase in reading times in the distractor words condition compared to the control conditions was more pronounced for older than for younger adults, $F(1, 153) = 35.04$, $p < .01$, $\eta^2 = .19$. Older adults were also slowed down more than younger adults by random letter strings, $F(1, 153) = 15.30$, $p < .01$, $\eta^2 = .09$, and by gaps in the text, $F(1, 153) = 5.23$, $p = .024$, $\eta^2 = .03$. The most interesting question was whether the age differences in distractibility would be moderated by the sensory acuity manipulation. If these age differences were primarily due to age-related sensory decline, we would expect an age difference in the control groups but not in the visual acuity reduction groups. However, there was no significant three-way interaction between age group, sensory acuity, and distractor condition, $F(3, 151) = 0.33$, $p = .81$, $\eta^2 = .01$, suggesting that sensory acuity did not moderate the age differences in distractibility. Does this mean that the sensory acuity manipulation had no effect on distractibility at all? This is also not the case, because there was a significant interaction between sensory acuity group and distractor condition, $F(3, 151) = 21.54$, $p = .01$, $\eta^2 = .30$, suggesting that participants with visual acuity reduction were slowed down more by distractor words, $F(1, 153) = 7.52$, $p = .01$, $\eta^2 = .05$, and random letter strings, $F(1, 153) = 64.34$, $p < .01$, $\eta^2 = .30$, than control participants. We conclude that reducing sensory capability increased interference somewhat but did not moderate the age differences in distractibility.

To further examine the age differences in distractibility, two 2 (age group) × 4 (distractor condition) MANOVAs were conducted for both sensory acuity groups separately. As expected, there was a significant interaction between age group and distractor condition for control participants, $F(3, 76) = 13.42$, $p < .01$, $\eta^2 = .35$. More important, the Age Group × Distractor Condition interaction was also significant when only participants with visual acuity reduction were analyzed, $F(3, 73) = 9.29$, $p < .01$, $\eta^2 = .28$, although effect size was slightly reduced. Thus, the age differences in distractibility can be replicated even when visual acuity is equated across all participants in both age groups. This finding shows that sensory decline cannot be responsible for the age differences in susceptibility to interference in the reading-with-distraction task.

Parallel to Experiment 1, we conducted an additional analysis (Duchek et al., 1998; Kim et al., 2007) in which we examined the proportional increase in reading time relative to the continuous control condition (see Figure 3, right panels). The relative increase in reading time was calculated by dividing the increase in reading time in the gap control, the random control, and the distractor words condition ($RT_{..}$) by the reading time in the continuous control baseline condition (RT_{CC}):

$$\frac{RT_{..} - RT_{CC}}{RT_{CC}}.$$

All conclusions derived from the analysis of the absolute reading times reported above were confirmed. Most important, the interaction between age group and distractor condition remained significant, $F(2, 152) = 6.69$, $p < .01$, $\eta^2 = .08$ (see Figure 3). It is interesting to note that when only participants with visual acuity reduction were examined, there were virtually no age differences in the relative increase in reading times due to gaps in the text, $F(1, 75) = 0.25$, $p = .62$, $\eta^2 < .01$, or random letter strings, $F(1, 75) = 0.60$, $p = .44$, $\eta^2 = .01$. Nevertheless, the age difference in distractibility by distractor words remained significant, $F(1, 75) = 8.11$, $p < .01$, $\eta^2 = .10$.

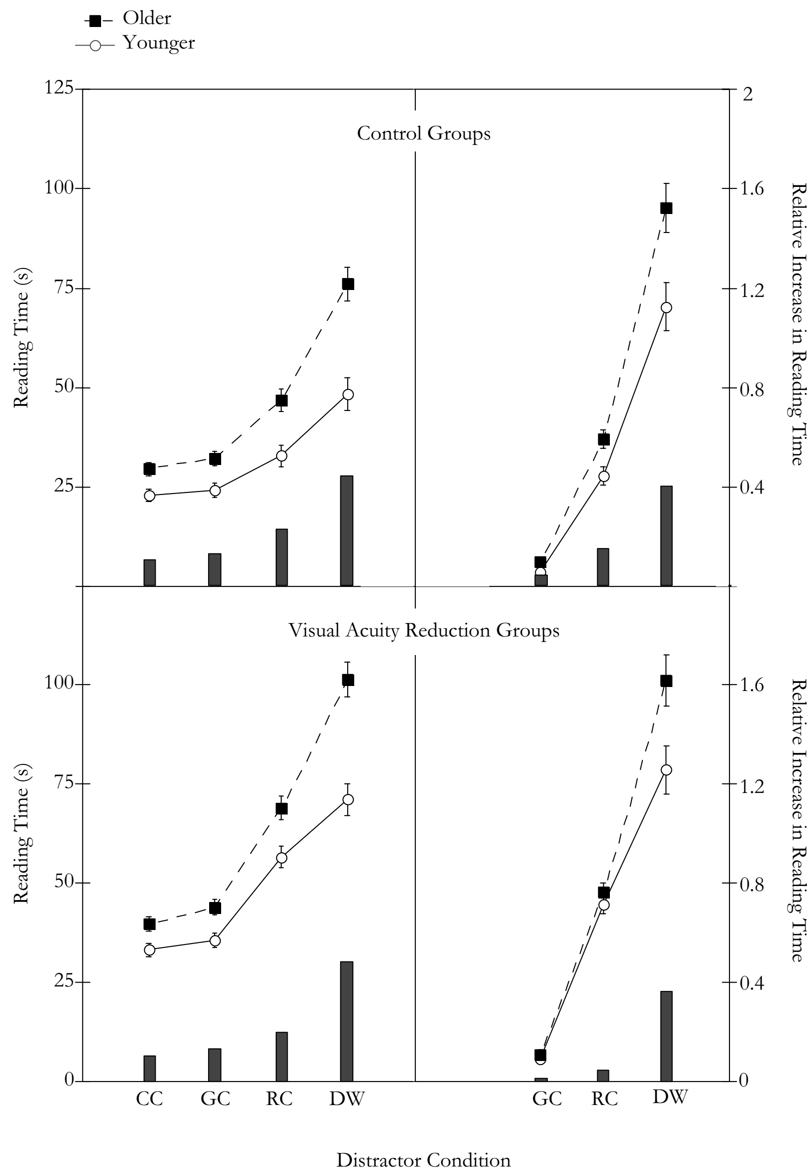

Figure 3. Reading times in Experiment 2. Left panels: Mean reading time as a function of distractor condition (CC = continuous control; GC = gap control; RC = random control; DW = distractor words) in the control groups (upper panel) and the visual acuity reduction groups (lower panel). Right panels: Mean increase in reading time relative to the continuous control condition in the control groups (upper panel) and the visual acuity reduction groups (lower panel): $\frac{RT_{..} - RT_{CC}}{RT_{CC}}$. The error bars represent the standard error of the means. The grey columns show the difference between age groups (older adults – younger adults).

Recognition test performance. The proportion of correctly identified target words in the 3-AFC recognition test is shown in Table 1. A 2 × 2 × 4 MANOVA with age group, sensory acuity group, and distractor condition as independent variables showed main effects of age group, $F(1, 153) = 123.16$, $p < .01$, $\eta^2 = .45$, and distractor condition, $F(3, 151) = 142.02$, $p < .01$, $\eta^2 = .74$, but no significant main effect of sensory acuity group, $F(1, 153) = 0.17$, $p = .68$, $\eta^2 < .01$. The target words were less often correctly identified in the distractor words condition than in the control conditions, $F(1, 153) = 427.02$, $p < .01$, $\eta^2 = .74$. Older adults correctly identified the target word less often than younger adults. As in Experiment 1, the interaction between age group and distractor condition was not significant, $F(3, 151) = 1.67$, $p = .18$, $\eta^2 = .03$. The interactions between sensory acuity and distractor condition, $F(3, 151) = 0.56$, $p = .64$, $\eta^2 = .01$, and the three-way interaction between age group, sensory acuity, and distractor condition, $F(3, 151) = 0.58$, $p = .63$, $\eta^2 = .01$, were also not significant.

Table 2 displays the proportion of falsely identified distractor words in the distractor words condition and the proportion of falsely identified new foil words (i.e., the absolute number of errors divided by the number of trials in which an error could be made). The errors in the distractor words condition were analyzed using a 2 × 2 × 2 MANOVA with age group (younger vs. older), sensory acuity (control vs. visual acuity reduction) and error type (distractor word vs. new foil word) as independent variables. This analysis revealed significant main effects of age group (older adults made more errors than younger adults), $F(1, 153) = 54.34$, $p < .01$, $\eta^2 = .26$, and error type (participants selected the previously presented distractor word more often than the new foil word), $F(1, 153) = 609.81$, $p < .01$, $\eta^2 = .80$. There was a significant interaction between age group and error type, $F(1, 153) = 9.67$, $p < .01$, $\eta^2 = .06$, in that older adults made more intrusions from the to-be-ignored material than younger adults. This finding stands in contrast to that of Experiment 1, where no age differences in distractibility were found in the 3-AFC recognition test, which may be attributed to the somewhat higher statistical power to detect age differences in this analysis in Experiment 2 relative to that of Experiment 1. It is important to note that there was no main effect of sensory acuity, $F(1, 153) = 0.45$ $p = .50$, $\eta^2 < .01$; no two-way interaction between sensory acuity and distractor condition, $F(1, 153) = 2.05$, $p = .15$, $\eta^2 = .01$; and no three-way interaction between sensory acuity, distractor condition, and age group, $F(1, 153) = 0.59$, $p = .44$, $\eta^2 < .01$. Thus, as in Experiment 1, sensory acuity had no influence on performance in the 3-AFC recognition test at all. Hence, sensory acuity affected reading times only.

Discussion

Experiment 2 shows that older adults are more susceptible to interference in the reading-with-distraction task than younger adults, even when all participants' visual acuity was equated so that there were no differences in visual acuity across both age groups. The visual acuity manipulation did not moderate age differences in the reading-with-distraction task. These findings clearly refute the sensory-deficit hypothesis, which implies that age differences in interference can be solely attributed to sensory decline. Nevertheless, the sensory acuity manipulation led to an increase in distractibility in the reading-with-distraction task. This result replicates the finding of Experiment 1 that sensory deficits may amplify susceptibility to interference in the reading-with-distraction task.

The three different types of control conditions—the continuous control condition, the gap control condition, and the random control condition—allowed for a more fine-grained analysis of the group differences in the reading-with-distraction task. There was only a very small difference in reading time between the continuous control and the gap control conditions. This difference was not affected by visual acuity. The age difference in the increase of reading times due to gaps in the text was small and disappeared when the proportional increase in reading time was analyzed. We may therefore conclude that the gap control condition can indeed be regarded as an adequate baseline condition. Using random letter strings as distractors caused an increase in reading time relative to the other two control conditions, even though interference was much less pronounced than when meaningful distractor words were used. Sensory acuity reduction considerably increased interference by random letter strings. In contrast, the difference between the two age groups in the relative increase in reading time was comparatively small and was abolished when visual acuity was equated. Thus, the small age difference in the increase in reading times due to random letter strings in the control groups may be solely attributed to sensory deficits. The age differences in the increase in reading times due to meaningful distractor words, however, were much larger and persisted even when visual acuity was equated between the age groups. These age differences in the susceptibility to lexical and semantic interference therefore cannot be fully attributed to age-related sensory deficits. Instead, these age differences seem to arise from declines of higher cognitive processes, such as a decline of inhibitory control. The simplest explanation for the pronounced age differences in the distractor words condition is that similarity between targets and distractors increases interference, and the likelihood of finding significant age differences increases with the amount of interference elicited by the distractors. An alternative interpretation of the present results is that older adults are particularly impaired by meaningful irrelevant information. This interpretation of the results would be consistent with studies examining age differences in cross-modal interference (Bell & Buchner, 2007; Bell et al., 2008), which suggest that age differences in susceptibility to cross-modal interference may be restricted to situations in which meaningful information has to be ignored.

General Discussion

The present experiments allow us to derive the following conclusions. First, and most important, the age-related increase in susceptibility to interference in the reading-with-distraction task is clearly not due solely to perceptual deficits of older adults but arises primarily from cognitive deficits at a higher level of processing. This conclusion is mainly based on two findings: (a) Age differences in the reading-with-distraction task cannot be fully simulated by reducing visual acuity (Experiment 1); (b) age differences in the reading-with-distraction task persist even when visual acuity is adjusted to the same level across all participants in both age groups (Experiment 2).

The finding that the age-related increase in distractibility cannot be fully attributed to sensory problems of older adults is consistent with the inhibitory-deficit hypothesis (Hasher et al., 2007), which assumes that older adults have a deficit in controlling the access of to-be-ignored information to working memory. The assumption of age-related deficits in selective attention is highly plausible, given that selective attention seems to rely on frontal lobe functioning, and it is well documented that the frontal lobe is one of the brain structures that degenerates most with increasing age (West, 1996). The finding that age-related differences in sensory capability are not the only cause of age differences in distractibility is also consistent with findings showing older adults to be more susceptible to cross-modal interference than younger adults when engaged in demanding working memory tasks (Bell et al., 2008; Meijer et al., 2006), which cannot easily be attributed to age-related sensory decline.

The second important finding of the present experiments is that sensory impairment had a direct effect on the amount of interference in the reading-with-distraction task. Thus, although sensory decline alone cannot fully explain the age-related differences in distractibility, the influences of sensory capability on measures of visual selective attention should not be ignored. In both experiments, the decrease in visual acuity led to an increase in reading time and—more important—an increase in distractibility, as measured by the difference in reading times between the distractor words condition and the control conditions. Therefore, it is possible that sensory problems may be responsible for some part of the age differences in visual selective attention obtained in previous studies in which older and younger adults differed in sensory capabilities to unknown degrees. In principle, this could have led to an overestimation of attentional decline in older adults. When differences in sensory capabilities are not controlled, distractibility in the reading-with-distraction task must not be viewed as a pure measure of inhibitory capacity. Thus, future studies that examine age differences in perceptually demanding visual selective attention tasks should take sensory capability into account. According to Schneider and Pichora-Fuller (2000), the problem that age differences in sensory acuity may amplify age differences in selective visual attention is generally ignored in cognitive aging studies. Further research is needed to examine whether the finding that sensory capability influences susceptibility to interference is confined to the reading-with-distraction paradigm or whether it is a more general problem that sensory capability affects measures of visual selective attention.

Although sensory capability affected distractibility, this effect was not very large. The visual acuity manipulation influenced reading times only and had no effect on the results of the recognition test at all. This suggests that the present results should not be interpreted as providing evidence for a general reduction of attentional performance due to sensory impairments. Instead, the results suggest that the effects of sensory acuity on cognitive performance may be confined to selective attention tasks, which are perceptually demanding in that targets and distractors are difficult to discriminate at a perceptual level. This interpretation is in line with the results of Lindenberger et al. (2001), who have shown that a sensory acuity manipulation similar to the one used in the present experiments had no influence on various measures of cognitive functioning such as processing speed, reasoning, episodic memory, and verbal fluency.

In summary, age differences in the reading-with-distraction task are affected by but are not solely due to a decline of visual acuity. Instead, these age differences are mainly caused by a decline of cognitive processes, such as a decrease of inhibitory attention. Nevertheless, sensory acuity has to be taken into account as a potential confounding factor in perceptually demanding visual attention tasks and should be carefully controlled in studies examining age differences in selective attention.

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Received December 21, 2009
Revision received March 5, 2010
Accepted March 5, 2010 ■

Aging and interference in story recall

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Abstract

Studies using a multiple-choice recognition test to examine age differences in the impairment of text comprehension due to distractors yielded inconsistent results. In the present study, participants were required to recall texts comprising unrelated, related, or no distractor words. Recall protocols were analyzed using a gist-based propositional scoring procedure. Older adults' story recall was clearly impaired by the presence of distractor material, whereas younger adults' recall performance was not. The findings suggest that older adults were more likely than younger adults to build up incorrect memory representations that comprise distractor concepts when distracting information was present.

Keywords: Text Recall, Prose Recall, Inhibition deficit theory, Inhibitory deficit theory, Text Comprehension, Cognitive Aging

Aging and interference in story recall

According to inhibitory deficit theory (Hasher & Zacks, 1988), cognitive aging is characterized by a reduction of inhibitory control over the contents of working memory. Most importantly for the present research, it is assumed that cognitive performance declines in old age because older adults fail to inhibit the processing of task-irrelevant extraneous information. One of the most frequently cited findings that supports inhibitory deficit theory is that older adults are more impaired than younger adults by the presence of distractor words when reading (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Dywan & Murphy, 1996; Feyereisen & Charlot, 2008; Kim, Hasher, & Zacks, 2007; Li, Hasher, Jonas, Rahhal, & May, 1998). In a typical experiment using the reading-with-distraction task, participants are required to read aloud short texts. In the experimental condition, to-be-ignored words in a distinct font style (upright font) are interspersed among the target text (printed in italic font). Usually, the increase in reading time in the distractor condition relative to a control condition without distractors is larger for older adults than for younger adults. Recent results show that these age differences are not solely due to sensory deficits of older adults, but arise from deficits in higher cognitive processes (Mund, Bell, & Buchner, in press). Mund et al. examined whether the age differences in distractibility prevail when visual acuity is equated between age groups. A priori, it seemed possible that older adults with sensory problems may fail to discriminate between target and distractor material at a perceptual level because they fail to see the subtle differences between different font styles. However, although visual acuity reduction increased interference somewhat, it did not eliminate the large age differences in distractibility as measured by the reading-time difference between the distractor condition and the control condition.

Another problem with interpreting the age differences in the slowing of reading time due to distractor words is that reading times of older and younger adults may already differ in the control condition in which no distracting information is present. In such cases the age-related increase in reading times in the distractor condition could be attributed to general age-related slowing rather than to a problem with interference control. There are only two studies that take age-related slowing into account by reporting the proportional increase in reading time relative to the baseline control condition (Kim et al., 2007; Mund et al., in press).[1] In one study the age difference in distractibility persisted in this analysis (Mund et al., in press), in the other it disappeared (Kim et al., 2007). Another problem when interpreting age differences in the slowing of reading speed is that old age may be associated with increased emphasis on accuracy as opposed to processing speed (Brébion, 2001, 2003). It is therefore conceivable that older adults put more emphasis on text comprehension while younger adults put more emphasis on reading speed. If this were true for the reading-with-distraction task, then older adults would read more slowly, and their reading times would increase disproportionally in those condition in which text comprehension is complicated by the presence of meaningful distractors. Thus, the age differences in the increase in reading times due to distractor material cannot be unambiguously interpreted unless text comprehension is also assessed.

In most studies examining age differences in the reading-with-distraction task, text comprehension is assessed using a multiple-forced choice (MFC) text recognition test. In this test, participants are required to identify previously read target words among new words and previously ignored distractor words. Two findings from the MFC text comprehension test support inhibitory deficit theory. First, the decrease of memory for the target words in the distractor condition relative to the control condition is larger for older than for younger adults. Second, older adults make more intrusion errors (i.e., choose the previously to-be-ignored distractor more often) than younger adults.

However, evidence from the MFC recognition test in favor of the inhibitory deficit account is much less compelling than generally thought. Table 1 shows all studies we know of in which tests of statistical significance of age differences in the MFC recognition test were reported. Only two out of thirteen experiments found that the presence of distractor words impaired the ability to detect the target word to a greater extent in older adults than in younger adults. Only three studies out of nine found an increase of intrusions from the to-be-ignored material in old age. In sum, these results would be consistent with the assumptions that age differences in distractibility in the reading-with-distraction task are either particularly small or do not exist at all (considering that one out of twenty statistical tests to the conventional level of $\alpha = .05$ would be significant due to chance, and assuming that there may be a publication bias towards reporting significant age differences in the predicted direction). The lack of reliable age differences in text comprehension is especially problematic for inhibitory deficit theory given that the interpretation of the age-related increase of reading times in the distractor condition is also difficult due to problems such as how to take age-related slowing into account adequately. The inconsistent outcome of the studies examining text comprehension with the MFC recognition test may be due to the poor psychometric properties of this test (Darowski et al., 2008). As a first step, one may thus recommend that the psychometric properties of the text-comprehension test should be improved (e.g., by increasing the number of items).

However, at a more general level it may be considered questionable whether a MFC recognition test allows to assess text comprehension appropriately. When reading, we usually direct our attention to, and subsequently remember the *meaning* of the text rather than the specific wording, that is, the perceptual components of a text. Most theories of text comprehension (McNamara & Magliano, 2009) assume that the memory representations for texts can be best described as a connectionist semantic network, consisting of nodes and links varying in activation strength. This is in line with working memory models such as the embedded-processes model (Cowan, 1995, 1999) which imply that the mental representation of the text is established by directing the focus of attention towards the semantic content of the words in long-term memory. One of the most important functions of the attentional component of working memory is its capacity to form new associations between activated memory representations (cf. Oberauer, 2005a, 2005b). When reading, the focus of attention serves to bind together activated semantic representations to establish new links between the semantic concepts, resulting in the construction of a mental representation of the meaning of the target text. The MFC recognition test may not be the best method to assess text comprehension and the subsequent retention of meaning for several reasons. This is so because participants are required to identify the target word among false alternatives that differ from the target word at a perceptual-lexical level, but not (or only marginally) at a semantic level (e.g., “digging tools” vs. “digging equipment”). Failing to distinguish between these perceptually and lexically different but semantically equivalent alternatives is hardly evidence for an impairment in text comprehension. It follows from these considerations that a more adequate measure of text comprehension must be particularly sensitive to the semantic content of the text rather than to its surface features. It has long been known that free recall has these properties (e.g., Srinivas & Roediger, 1990), but none of the published reading-with-distraction studies we know of has ever used a free recall test to assess the mental representation of the whole texts.[2] Therefore, we examined age differences in the reading-with-distraction paradigm using a memory test requiring free recall of whole texts. As will be shown in the *Discussion* section, the free recall test used here also yields a much more reliable memory measure than the MFC recognition test, which helps solving the problem explicated in the preceding paragraph.

Three conditions were contrasted, a *control* condition, in which the texts were presented continuously, an *unrelated* distractor condition, in which the distractor words were unrelated to the meaning of the target text, and a *related* distractor condition, in which the target words were related to the meaning of the target text. As in other studies examining age differences in text comprehension (e.g. Johnson, 2003; Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow, Shake, Miles, & Noh, 2006), we analyzed the number of propositions that were correctly recalled, using a gist-based scoring criterion. This allowed us to assess whether participants had an accurate representation of the *meaning* of the target text independent of its surface structure (Turner & Greene, 1987). We were especially interested in how the distractors would corrupt the mental representation of the target text in younger and older adults.

Method

Participants

47 older adults and 46 younger adults participated in the experiment. Data from three participants (two older adults and one younger adult) with a diagnosis of "mild cognitive impairment" in the DemTect (a sensitive dementia screening test; Kalbe et al., 2004) were excluded from data analysis. The remaining 45 older adults (30 women) ranged in age from 60 to 82 years (M = 68, SD = 5). The remaining 45 younger adults (26 women) ranged in age from 19 to 30 years (M = 24, SD = 3). Younger adults had more years of education than older adults, $F(1,88) = 15.45$, $p < .01$, $\eta^2 = .15$, but older adults performed better on a vocabulary test (MWT-A; Lehrl, 1989) than younger adults, $F(1,88) = 9.41$, $p < .01$,

$\eta^2 = .10$. Older and younger adults did not differ with respect to their self-assessed overall contentment with life, $\chi^2(1) = 1.70$, $p = .19$. All participants were native German speakers. None of the participants had a history of heart attack, stroke, brain trauma, alcoholism, Parkinson's disease, or pulmonary emphysema or had taken medication that could influence cognitive functioning.

Materials

The reading-with-distraction task requires discriminating font styles (typically upright vs italic in an unfamiliar font) that may be hard to distinguish with decreased visual acuity. Previous research has shown that age-related sensory decline may increase interference from upright distractors in italic text to some degree, but also that the age differences in the reading-with-distraction task cannot be fully explained by age differences in sensory acuity. In order to make sure that possible age differences in distractibility cannot be attributed to age differences in the failure to discriminate font styles at a perceptual level, we used glasses with partial occlusion filters (Ryser Optik; St. Gallen, Switzerland) to artificially reduce younger participants' visual acuity to the acuity measured in the group of older participants. This method has proven successful in previous studies (Lindenberger, Scherer, & Baltes, 2001; Mund et al., in press). Specifically, there are several types of partial occlusion filters that reduce visual acuity to different degrees. Younger participants were tested with filters that lowered their visual acuity to that of a (randomly) matched older adult. Visual acuity was assessed using a well established and validated visual computerized screening test (FrACT; Bach, 2007) with good psychometric properties. The test uses simple Landolt C optotypes and thus allows measuring "pure" visual acuity not confounded by higher cognitive processes that would be involved in an acuity test with, for instance, to-be-read words, sentences, or longer texts. The FrACT was run on the same (24 inch) computer monitor that was used for the experiment proper. Both age groups performed the FrACT before (pretest) and after visual acuity adjustment (posttest). A chin rest and a forehead rest were used to ensure that participants had a viewing distance of 110 cm to the computer screen during the entire experiment.

For the reading-with-distraction task, we used the same 20 texts as in Mund et al.'s (in press) study (dictation texts selected from school books used in 7th or 8th grade). All texts were 60 words long. On average, each text comprised 5 sentences ($SD = 1$) and 25 propositions ($SD = 3$). As in previous studies

(Connelly et al., 1991; Kim et al., 2007), the to-be-read target texts were presented in black italic Courier font on a white background. Each character subtended about 0.29° vertically and 0.21° horizontally. Fifteen texts were randomly selected as target texts, five in each of three distractor conditions (*continuous control, unrelated, related*). The texts were randomly assigned to the conditions on an individual basis. In the *continuous control* condition, the target texts were written continuously without distractor words. In the conditions with distracting material 30 distractor words (3 unique distractor words repeated 10 times) written in upright font were randomly interspersed into the target text with the constraint that no distractor word followed another distractor word directly and that the first and the last word of the text were no distractor words. For three nouns of each text, two semantically related words were selected (e.g., *Dschungel* [jungle] and *Tropenwald* [tropical forest] were selected for *Regenwald* [rain forest], and *Kopfschmerzen* [headache] and *Zahnschmerzen* [toothache] were selected for *Bauchschmerzen* [stomachache]). One of these three alternatives was randomly selected for being used as an italicized target word that appeared at the correct position in the text. In the *related* distractor condition, one of the other two alternatives was randomly selected to be used as a distractor word, and the other was used as a control word for the analysis of the number of intrusions (see the *Procedure* section). In the *unrelated* distractor condition, the distractor words (and control words) were drawn from the five texts that were not selected for presentation. The texts were presented in random order.

Procedure

Participants were tested individually. They were required to read out loud the text presented on the computer screen. Two short sentences—one sentence comprising irrelevant distractor words and one without distractor words—were presented to familiarize the participants with the task. In a practice trial, participants read a complete text with *related* distractor words. The practice trial was followed by the 15 experimental trials. Each trial started with a countdown. Then the text appeared at the center of the screen. Participants were required to read out loud the italicized text without making pauses and without making errors. They were advised to ignore all words printed in upright font. When participants had read the last word of the text, reading time was recorded.

The main difference between the present study and Mund et al.'s (in press) study or other studies using the reading-with-distraction task is in the way in which text comprehension was assessed. The present study is the first study we know of in which free recall of whole texts was used, whereas most previous studies used an MFC recognition test to assess age-related effects of distractor words on text comprehension (we explicate in the Introduction why free recall is more appropriate than the MFC recognition test). A question mark that appeared in the middle of the screen was the signal for participants to recall the target text with as much detail as possible. Participants' answers were recorded by the computer's built-in microphone. When participants felt that they could not remember any more details, they gave the experimenter a signal to initiate the next trial.

For scoring purposes, a propositional analysis was performed on the texts using the system of Turner and Greene (1987) that is based on the text-comprehension model of Kintsch and van Dijk (1978). For instance, the sentences "The Meyers do not care about housekeeping. They love dirt." were decomposed into the propositions (CARE ABOUT, A: THE MEYERS, O: HOUSEKEEPING), (NEGATE, (CARE ABOUT, A: THE MEYERS, O: HOUSEKEEPING)) and (LOVE, A: THE MEYERS, O: DIRT). Participants' answers were transcribed and compared to the template text bases using a gist-based scoring criterion. Thus, propositions comprising synonyms of to-be recalled words were scored correct. To illustrate, if a participant would have remembered "The Meyers do not care about housekeeping. They like filth.", all of the propositions would have been scored as correct. To increase the reliability and validity of the scoring procedure, we used the *Projekt Deutscher Wortschatz* database (http://wortschatz.uni-leipzig.de/) to identify synonyms. The database is based on a huge collection of texts from various sources (e.g., newspaper articles, webpages) and thus represents a large portion of current-day word usage (see Biemann, Bordag, Heyer, Quasthoff, & Wolff, 2004). To evaluate the reliability of the propositional scoring procedure, the 150 recall protocols of ten randomly selected participants (5 younger and 5 older adults) were scored by an independent rater. Inter-rater agreement, as assessed by the kappa-coefficient (Cohen, 1960), was $\varkappa = .94$ (i.e., "almost perfect"; Landis & Koch, 1977).

In addition to the analysis of the propositional content of the recall protocols, a levels analysis was conducted according to the procedure outlined by Dixon, Simon, Nowak, and Hultsch (1982). This procedure is based on the assumption of Kintsch and van Dijk (1978) that each text consists of propositions which are connected and hierarchically ordered. A proposition *B* is subordinated to another proposition *A* when proposition *A* is either embedded in proposition *B* or when proposition *A* contains an argument that is repeated in proposition *B*. With proposition *A* assigned to the level *n*, the subordinated proposition *B* obtains the level $n + 1$. After decomposing the stories into the propositions contained, we specified the hierarchical structure of each story according to these rules. Following the procedure of previous studies (e.g. Adams, Smith, Pasupathi, & Vitolo, 2002), we subsequently summed the original raw scores for levels 1 and 2 representing the main ideas of the text and all levels of 3 and higher representing the details of the text in order to simplify the levels analysis.

To detect distractor intrusions, the words of the recall protocols were automatically compared to the word-stems of the distractor words and the control words using a computer program. If a word in the recall protocol matched the word-stem of a distractor word, the word was scored as an intrusion. However, not all distractor intrusions may be due to aftereffects of distractor presentation. In the *related* distractor condition, participants may paraphrase and add new information that may coincidentally match the distractor words. To control for spontaneous use of distractor words, we also analyzed intrusions from control words that were not presented as distractors. In both distractor conditions, it was randomly determined whether a specific word would be used as a distractor or as a control word. Therefore, differences in the rate of intrusions between these two types of words can only be attributed to aftereffects of distractor word presentation in the reading phase.

Design

A 2 × 3 design was used with group (*younger* vs. *older*) as between-subject factor and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as within-subject factor. The dependent variables were reading time, the proportion of correctly recalled propositions, and the number of intrusion errors. Given a sample size of 90 and assuming a correlation of $\rho = .5$ among the levels of the within-subject factor, an effect of size $f = 0.17$ (i.e., between small and medium effects as defined by Cohen, 1988) could be detected for the interaction between group and distractor condition with a probability of $1 - \beta = .95$ (Faul, Erdfelder, Lang, & Buchner, 2007). A multivariate approach was used for all within-subject comparisons. In the present application, all multivariate test criteria correspond to the same (exact) *F*-statistic, which is reported. Partial η^2 is reported as a measure of the size of an effect. The level of α was set to .05 for all analyses.

Results

Treatment check of the visual acuity manipulation

In the pretest (when younger adults were tested *without* partial occlusion filters), visual acuity was worse for older (*Md* = 0.88) than for younger adults (*Md* = 1.07), $z = -5.99$, $p < .01$. In the posttest (when younger adults were tested *with* partial occlusion filters), visual acuity was the same for older (*Md* = 0.92) and younger adults (*Md* = 0.85), $z = -1.65$, $p = .10$ (Figure 1), confirming that we succeeded in equating visual acuity between older and younger adults. Thus, age differences in distractibility cannot be attributed to older adults' failing to see the differences between italic and upright font because of age differences in visual acuity.

Reading times

A 2 × 3 MANOVA with age group (*younger* vs. *older*) and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables revealed a significant main effect of distractor condition, $F(2,87) = 224.75$, $p < .01$, $\eta^2 = .84$ (Figure 2). Orthogonal contrasts showed that participants read more slowly in the *unrelated* distractor condition than in the *continuous control* condition $F(1,88) = 415.94$, $p < .01$, $\eta^2 = .83$, and more slowly in the *related* than in the *unrelated* distractor condition, $F(1,88) = 45.84$, $p < .01$, $\eta^2 = .34$. There was also a main effect of age group, $F(1,88) = 13.31$, $p < .01$, $\eta^2 = .13$, that was qualified by an age group × distractor condition interaction $F(2,87) = 10.69$, $p < .01$, $\eta^2 = .20$. The interaction between age group and the variable contrasting the control condition with the two distractor conditions combined was significant, $F(1,88) = 20.25$, $p < .01$, $\eta^2 = .19$, suggesting that older adults were slowed down more by the presence of distractor words than younger adults. The interaction between age group and the variable contrasting the *unrelated* distractor condition with the *related* distractor condition was not significant, $F(1,88) = 0.09$, $p = .77$, $\eta^2 < .01$, suggesting that older adults were *generally* more impaired by distracting information. Remarkably, reading speed did not differ between older and younger adults when the texts contained no distracting material, $F(1,88) = 1.36$, $p = .25$, $\eta^2 = .02$. Large age differences emerged in the *unrelated* distractor condition, $F(1,88) = 16.10$, $p < .01$, $\eta^2 = .16$, and in the *related* distractor condition $F(1,88) = 14.58$, $p < .01$, $\eta^2 = .14$. The fact that age differences in reading speed were confined to the distractor conditions shows that the age difference in reading times in the distractor conditions cannot be attributed to age-related slowing and must be due to age-related problems in interference control. To facilitate the comparison of the results of the present studies with previous studies (Duchek, Balota, & Thessing, 1998; Kim et al., 2007; Mund et al., in press), we also analyzed the proportional increase in reading time in the distractor conditions relative to the control condition (that is, reading times in the distractor conditions divided by the reading time in the control condition). As expected, this analysis revealed a significant effect of age group on the proportional increase in reading time due to the presence of distractor words, $F(1,88) = 14.06$, $p < .01$, $\eta^2 = .14$.

Propositional recall

Figure 3 shows the proportion of correctly recalled propositions. A 2 × 2 × 3 MANOVA with age group (*younger* vs. *older*), level (*main ideas* vs. *details*), and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables revealed a significant main effect of age group, $F(1,88) = 30.15$, $p < .01$, $\eta^2 = .25$, suggesting that older adults recalled fewer propositions than younger adults. There was also a main effect of distractor condition, $F(2,87) = 11.71$, $p < .01$, $\eta^2 = .21$. Orthogonal contrasts showed that there was no significant difference between the *unrelated* distractor condition and the *continuous control* condition, $F(1,88) = 0.53$, $p = .47$, $\eta^2 = .01$, but participants recalled more propositions in the *unrelated* distractor condition than in the *related* distractor condition, $F(1,88) = 21.86$, $p < .01$, $\eta^2 = .20$. Moreover, there was a main effect of level $F(1,88) = 694.34$, $p < .01$, $\eta^2 = .89$, replicating the prevailing finding that the main ideas of texts are more likely to be recalled than the details of the texts

(Adams et al., 2002; Dixon et al., 2004). This level effect was reduced in older adults as indicated by the significant interaction between age group and level $F(1,88) = 4.84$, $p = .03$, $\eta^2 = .05$. Consistent with other findings (e.g. Dixon et al., 1982; Meyer & Rice, 1981; Stine, Wingfield, & Poon, 1986), it seems that younger adults are better than older adults at discriminating between the (presumably more important) main ideas and the (less important) details of the texts, resulting in a reduction of the level effect. All other interactions involving the level-variable did not attain the conventional level of significance.

The most interesting question was whether we would find age differences in distractibility, i.e. in the impairment of propositional recall due to irrelevant information. Consistent with predictions derived from inhibitory deficit theory, the age group × distractor condition interaction was significant, $F(2,87) = 8.32$, $p < .01$, $\eta^2 = .16$. Older adults' propositional recall was clearly impaired by unrelated distractor words, $F(1,44) = 7.89$, $p = .01$, $\eta^2 = .15$, and was even more impaired by related distractor words than by unrelated distractor words, $F(1,44) = 12.09$, $p < .01$, $\eta^2 = .22$. Younger adults, in contrast, showed an increase in propositional recall in the *unrelated* distractor condition in comparison to the *continuous control* condition $F(1,44) = 8.71$, $p = .01$, $\eta^2 = .17$. This paradoxical effect can be explained by assuming that younger adults successfully increased their reading efforts as a response to the increased reading difficulty caused by the distractors relative to the *control* condition. In particular, they may have attended more to the meaning of the target text in the *unrelated* distractor condition than in the *control* condition to avoid interference. Note that in the *unrelated* distractor condition, concentrating on the meaning of the text may be an efficient countermeasure against interference because it helps to discriminate between target and distractor materials that differ markedly in their semantic properties. This compensatory strategy is not useful in the *related* distractor condition because of the semantic relatedness of the distracting material. This may be the reason why younger adults' recall in the *related* distractor condition decreases when compared to the *unrelated* distractor condition. Older adults, however, seem to be less able than younger adults to adjust their reading efforts to support interference avoidance, which results in a significant decrease of memory performance in the *unrelated* distractor condition as compared to the *continuous* control condition. However, the global interaction of age group and distractor condition is not solely due to younger adults' enhanced memory performance in the *unrelated* distractor condition. If only the *continuous control* condition and the *related* distractor condition were included in this analysis, the interaction between age group and distractor condition persists, $F(1,88) = 9.57$, $p < .01$, $\eta^2 = .10$. Thus, older adults' propositional recall was clearly impaired by the distracting material, whereas younger adults' recall performance was not.

The analysis of the intrusion errors also revealed evidence for age differences in interference control (Figure 4). Older adults produced more intrusions from related distractor words than younger adults, $F(1,88) = 9.10$, $p < .01$, $\eta^2 = .09$. In contrast, very few control words were produced and there were no age differences in the production of control words, $F(1,88) = 0.05$, $p = .83$, $\eta^2 < .01$. Thus, intrusions from related distractor words cannot simply be attributed to older adults remembering less and paraphrasing more than younger adults. Intrusions from unrelated distractor words were less frequent than intrusions from related distractor words. This was to be expected given that these unrelated distractor words did not fit the target text at all. Nevertheless, the same data pattern was obtained for unrelated distractor intrusions and for related distractor intrusions. Older adults made more intrusions from unrelated distractor words than younger adults $F(1,88) = 14.11$, $p < .01$, $\eta^2 = .14$, but there was no age difference in the number of intrusions from unrelated control words (that were not presented as distractors), $F(1,88) = 0.65$, $p = .42$, $\eta^2 = .01$.

Discussion

The present study revealed pronounced age differences in reading with distraction, as predicted by inhibitory deficit theory (Hasher & Zacks, 1988). Age differences were equally pronounced in the *unrelated* and the *related* distractor condition. This suggests that these age differences can be attributed to general problems with interference control rather than to specific problems with rejecting related material (e.g., a broader activation of semantically related concepts in older adults' working memory).

Consistent with previous studies, older adults were slowed down more by the presence of distractor words than younger adults when reading. This finding has been previously attributed to older adults' decreasing visual capabilities that may increase distractibility in the reading-with-distraction task because this task requires discrimination of subtle perceptual differences between target and distractor font styles (Bell & Buchner, 2007; Bell, Buchner, & Mund, 2008; Burke & Osborne, 2007; Burke & Shafto, 2008). The present study can rule out this alternative explanation of age differences in reading with distraction, because visual acuity was equated between older and younger adults. Thus, the increase in distractibility in older adults cannot be attributed to age-related sensory decline. This replicates the finding of Mund et al. (in press) that age differences in the original version of the reading-with-distraction task persisted when age differences in visual acuity were taken into account by adjusting younger and older adults' visual acuity so that there were no differences in visual acuity across both age groups. Age differences in the increase in reading times due to the presence of distractor words persisted when cognitive slowing was taken into account by analyzing the proportional increase in reading times in the distractor conditions relative to the control condition, which also replicates the findings of Mund et al. It is reassuring to see that the age difference in the slowing of reading by distractors persists when a free-recall test following each reading phase required both younger and older adults to focus on text comprehension.

The most important question was whether we would find evidence that older adults' memory for the texts would be more impaired by the distractor words than that of younger adults. Consistent with the hypotheses derived from inhibitory deficit theory, we found that the decrease in propositional recall in the distractor conditions was more pronounced for older adults than for younger adults, and that older adults produced more intrusions from both related and unrelated distractor words than younger adults. Given that previous studies examining age differences in text comprehension with a MFC recognition test yielded highly inconsistent results (see Table 1), it seems notable that we found evidence for an increased distractibility of older adults in all dependent variables. The simplest explanation of this fact together with the inconsistency in previous studies is that the psychometric properties of the propositional-recall score and the MFC recognition test score differ. The reliability of the MFC recognition test score is rather poor. For instance, in Experiment 1 of Mund et al. (in press), Cronbach's alpha across age groups was .40 in the *control* condition and .48 in the *related* distractor condition. Reliability was equally low in other studies using the reading-with-distraction task. For instance, Darowski et al. (2008) reported a reliability of .42 in the *control* condition and of .41 in the *related* distractor condition. In contrast, the reliability of the propositional-recall score obtained in the present study was .71 in the *control* condition and .79 in the *related* distractor condition. Thus, the failure in many studies to obtain significant age differences in the decrease of text comprehension due to the presence of distractor words is probably due to the low reliability of the MFC recognition test score rather than to preserved inhibitory functioning in older adults. We think it reasonable to assume that the MFC recognition test's reliability is low because it is a poor measure of text comprehension, as outlined in the introduction, such that the observed MFC recognition test score can be conceived of as a combination of a small text comprehension true score and a large measurement error component.

However, the present results not only confirm the existence of age differences in the impairment of text comprehension due to verbal distractors; they also allow for a more detailed and a more valid assessment of distractibility in the reading-with-distraction task. The age-related decrease of propositional recall in the distractor conditions suggest that older adults were less able than younger adults to establish a mental representation of the target text when distractor words were present. Due to deficits in inhibitory control, older adults may be more likely to process distracting material than younger adults, which may draw attentional resources away from the binding of the semantic concepts that constitute the target text. The finding that younger adults had even better recall performance in the *unrelated* distractor condition than in the *control* condition suggests that the age differences in interference may, in part, be due to younger adults' compensatory strategy efforts to avoid interference. In the *unrelated* distractor condition, younger participants may place greater emphasis on text comprehension because this helps them to reject the unrelated distractor words. This strategy cannot help in the *related* distractor condition, which may result in a drop in propositional recall in this condition when compared to the *unrelated* distractor condition. This interpretation is consistent with the finding that younger adults are better able than older adults to apply flexible strategies according to the particular demands of a reading task (Stine-Morrow et al., 2006). Thus, the more sensitive text-comprehension test used in the present study allowed us to detect age differences in the strategic use of semantic encoding strategies that would not have been detected by the insensitive MFC recognition test. The finding suggests that future studies should take into account the participants' active role in interference avoidance by examining whether older adults differ in the use of strategies that help them to cope with the demands of selective-attention paradigms.

Older adults also made more intrusions from related distractor words than younger adults. This finding could be explained by assuming that the irrelevant information enters the focus of attention, where it intrudes into ongoing cognitive operations such as binding word concepts to propositions. In the related distractor condition, the semantic representations of the target words and the distractor words differ only marginally or are even identical. Potter and Lombardi (1990) examined interference in a similar paradigm. They required participants to learn sentences. Before sentence recall, participants were required to read a list of words that comprised a synonym of one of the words in the sentence. These lure words were frequent intrusions, but only when they were semantically related to the meaning of the sentence. Potter and Lombardi suggested that during recall, the sentence had to be regenerated from a conceptual representation of the meaning of the sentence, using recently activated lexical entries. The intrusions of related distractor words in the reading-with-distraction task can be explained using the same assumptions. Some of the related distractor words are synonyms of words in the to-be recalled text (i.e., they share the same conceptual representation). If processing of the distractor word is not suppressed, the lexical representation of the distractor word may be more activated than the lexical representation of the target word given that the distractor word was presented more frequently than the target (ten times vs. once). Thus, intrusions from related distractor words could be explained by assuming that participants regenerate the to-be recalled story from a correct conceptual representation of the target text, using the highly accessible lexical entries of the distractor words.

However, this explanation cannot be applied to the finding that older adults made more intrusions from *unrelated* distractor words than younger adults. In this condition, distractor words did not fit the to-be recalled texts at all. Therefore, this suggests that the semantic concepts of the distractor words were integrated into the mental representation of the text. To illustrate, instead of remembering "Each point of the globe can be reached. We can wake up in a different country every morning because airplanes and trains are always available...", an older participant included as an intrusion the unrelated distractor word “rain forest” by remembering “It is always possible to go everywhere via train and airplane, to go for a walk in the rain forest or to wake up in a different country every morning...”. Note that—at least in terms of standardized effect size, the age difference in the number of intrusion errors were equally large in the *unrelated* distractor condition and in the *related* distractor condition, suggesting that older adults may fail to prevent distractor content from entering the focus of attention. As a consequence, the distractor information is at least occasionally built into the mental representation of the target text.

In summary, we used a propositional scoring procedure to analyze how distractor words interfere with story recall. Older adults showed a more pronounced decrease of propositional recall due to the presentation of distractor words than younger adults. This suggests that older adults were less able than younger adults to establish a correct mental representation of the text when distractor words were present. The analysis of distractor intrusions suggested that older adults were more likely than younger adults to build up incorrect memory representations that comprise distractor information. We conclude that there are pronounced age differences in the impairment of text comprehension by distracting information.

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Footnotes

[1] Duchek et al. (1998) report an analysis of proportional increase in reading time relative to the control condition, but they report only the global interaction between distractor condition and group, and they examined younger adults, older adults, and Alzheimer's patients. Therefore, it is unclear whether the significant interaction between group and condition can be attributed to the effects of normal aging.

[2] Note that Li et al., (1998) converted the MFC questions into a cued recall task, in which participants were asked to recall the target word. Obviously, this procedure is also not suited to reveal age differences in the susceptibility to interference within the mental representation of a whole text, i.e. a network of activated semantic concepts and their connections.

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Table 1

Results of the MFC-recognition test used by previous studies regarding age differences in susceptibility to interference. "Yes" indicates findings that suggest an age-related increase in distractibility (i.e., a significant interaction between age group and distractor condition), "No" indicates the absence of age differences in distractibility. Studies marked with a hyphen (-) did not report the relevant comparison of distractibility as a function of age group in the particular variable.

Authors	Year	Experiment	Age Difference in Memory for Target Words	Age Difference in Intrusion Errors
Connelly, Hasher & Zacks	1991	1	No	No
		2	No	No
Carlson, Hasher, Connelly & Zacks	1995	1	No	No
		2	No	No
		3	Yes	Yes
Dywan & Murphy	1996	1	No	Yes
Duchek, Balota & Thessing	1998	1	No	No
Phillips & Lesperance	2003	1	No	-
Kemper & McDowd	2006	1	No	-
Kemper, McDowd, Metcalf & Liu	2008	1	Yes	-
Feyereisen & Charlot	2008	1	No	-
Mund, Bell & Buchner	2010	1	No	No
		2	No	Yes

Figure Captions

Figure 1: Visual acuity in Snellen decimals for the two groups in both visual acuity tests. Each marker represents the visual acuity of one participant.

Figure 2: Mean reading time as a function of distractor condition and group. The error bars represent the standard errors of the means.

Figure 3: Mean percent of correctly recalled propositions as a function of distractor condition and group. The error bars represent the standard errors of the means.

Figure 4: Mean number of intrusion errors as a function of word type and group. Left panel: Mean number of intrusion errors in the *related* distractor words condition. Right panel: Mean number of intrusion errors in the *unrelated* distractor words condition. The error bars represent the standard errors of the means.

Figure 1

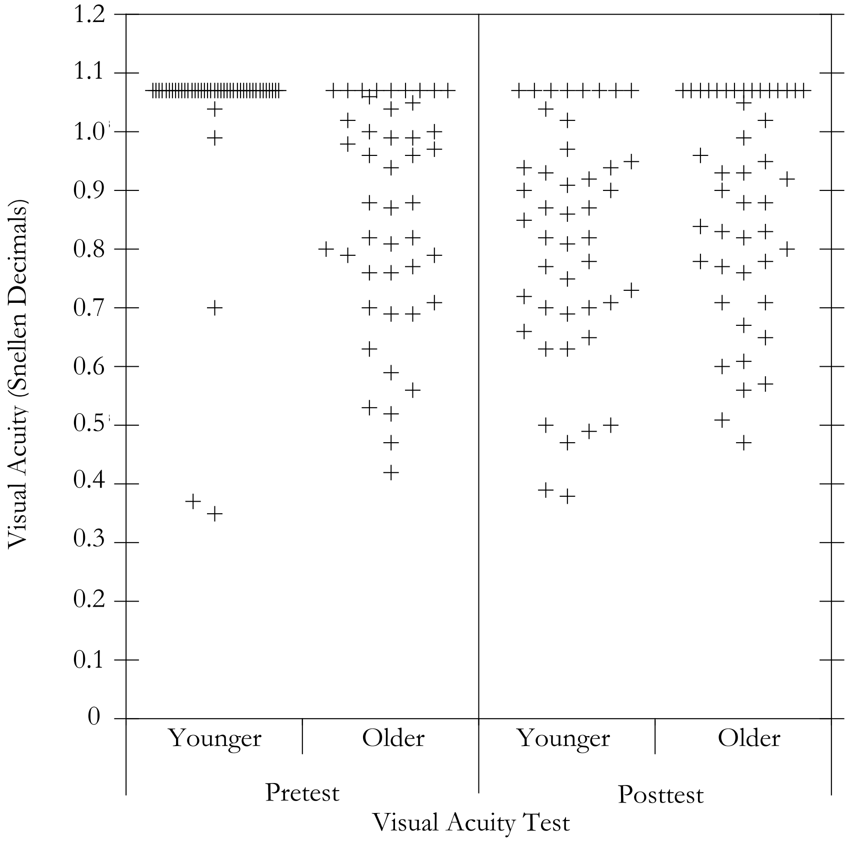

1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Visual Acuity (Snellen Decimals)
Younger
Older
Younger
Older
Pretest
Posttest
Visual Acuity Test

Figure 2

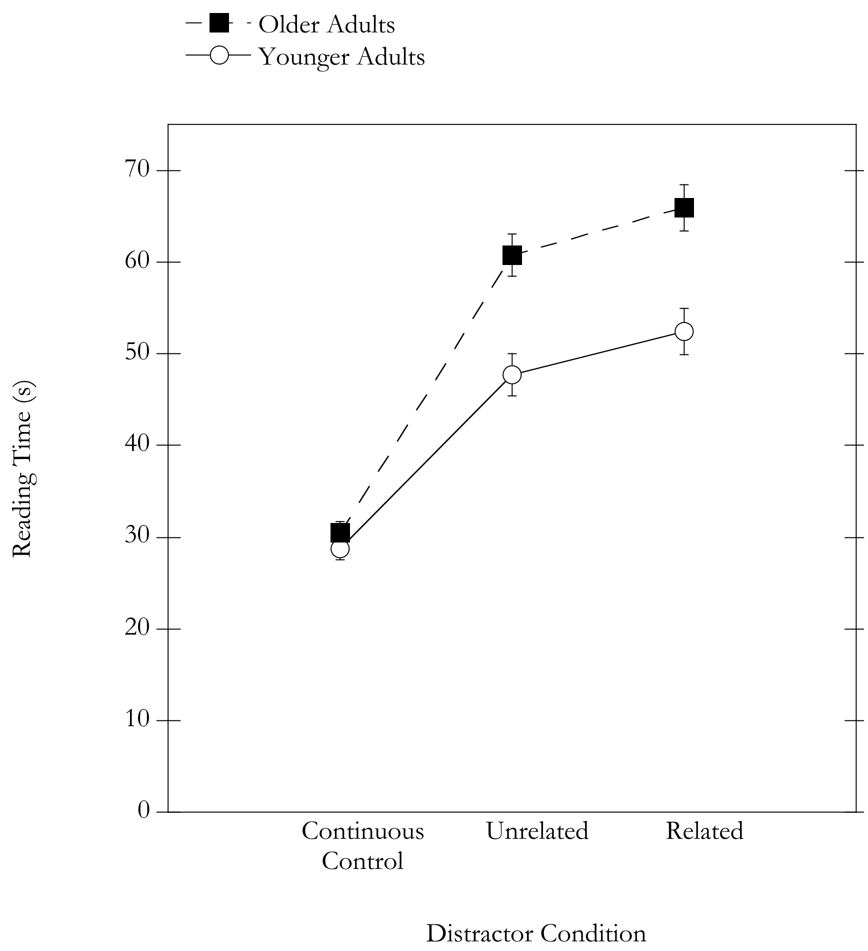

Older Adults
Younger Adults
Reading Time (s)
70
60
50
40
30
20
10
0
Continuous Control
Unrelated
Related
Distractor Condition

Figure 3

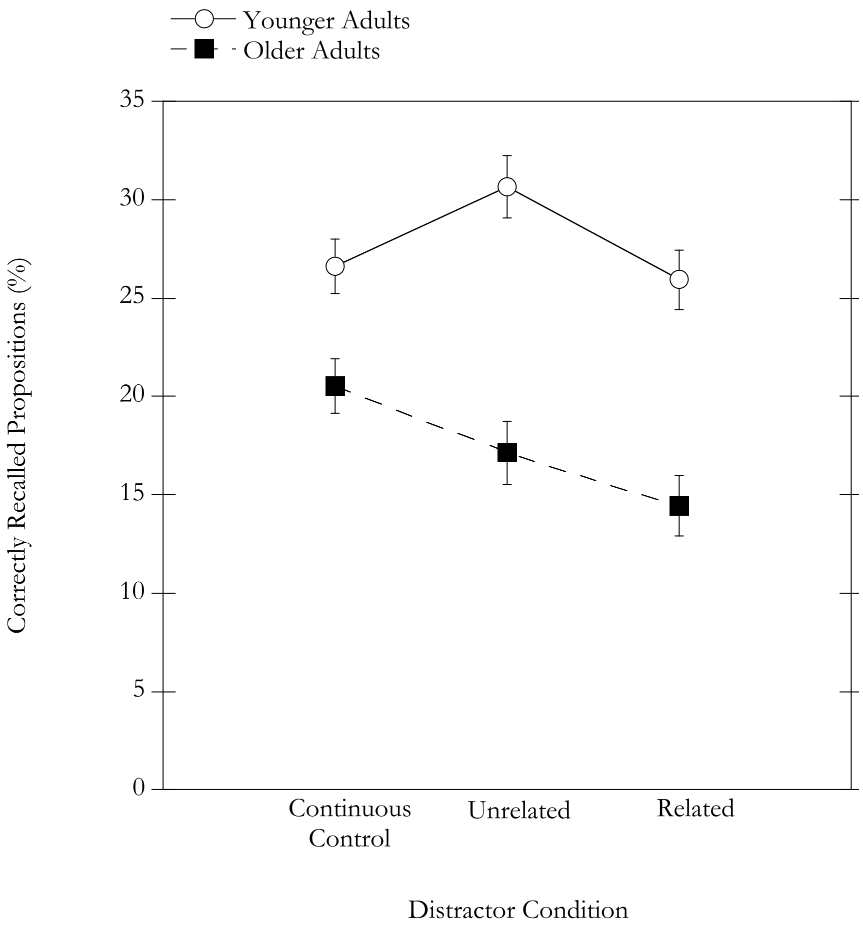
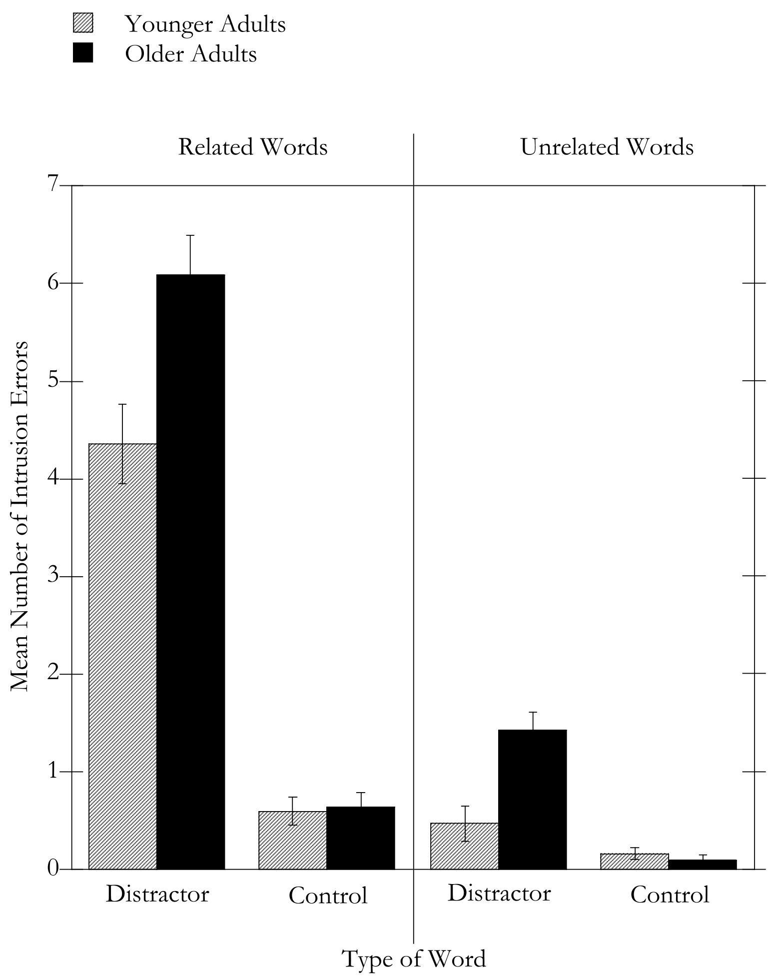

Younger Adults
Older Adults
35
30
25
20
15
10
5
0
Correctly Recalled Propositions (%)
Continuous
Control
Unrelated
Related
Distractor Condition

Figure 4


Younger Adults
Older Adults
Related Words
Unrelated Words
Mean Number of Intrusion Errors
0
1
2
3
4
5
6
7
Distractor
Control
Distractor
Control
Type of Word

Reading with Distraction: Similarities and differences between older and younger adults

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Running Head: Age Differences in Reading With Distraction

Abstract

Age differences in the reading-with-distraction paradigm are often cited as evidence for a decline in inhibitory control in old age. In the present study, participants were required to read texts with and without distractor words with a focus on text comprehension. The moving-window-method was used to assess reading times for target and distractor words separately. Contrary to predictions derived from inhibitory deficit theory, the analyses of the reading times at the level of single words revealed no age differences in online text processing in the presence of distractor words. A free recall test showed that older and younger adults' memory for the texts was equally impaired by the presence of distractor information. The results are inconsistent with the assumption that age differences in reading-with-distraction can be explained by a general decline in inhibitory attention.

Keywords: Inhibitory Deficit Theory, Moving Window Method, Cognitive Aging, Selective Attention, Text Comprehension

Reading with Distraction: Similarities and differences between older and younger adults

Cognitive aging is characterized by declines in various cognitive functions such as attention, memory, speech production, and comprehension (Light, 2000; McDaniel, Einstein, & Jacoby, 2008; Zacks, Hasher, & Li, 2000). One of the most influential theoretical accounts of cognitive aging is the inhibitory deficit theory (Hasher & Zacks, 1988). This theory proposes that the age-related changes in cognitive functioning can be attributed to a general deficit in inhibitory attentional control over the contents of working memory. Inhibitory control serves three functions, all of which are assumed to be deficient in old age (Hasher, Zacks, & May, 1999). (1) The *access function* serves to prevent irrelevant information from entering working memory; (2) the *deletion function* is responsible for deleting no longer relevant information from working memory; and (3) the *restraint function* suppresses dominant, but inadequate response tendencies. The main focus of this article is on the *access* function of inhibitory control. With a deficit in this function, older adults are less able to inhibit the processing of extraneous distractors. As a consequence, irrelevant information gains access to working memory, where it interferes with the processing of relevant information. A large amount of evidence supports the prediction of inhibitory deficit theory that older adults should be more susceptible to distraction than younger adults. For instance, older adults are more disrupted by meaningful irrelevant background speech than younger adults when trying to memorize verbal material (Bell, Buchner, & Mund, 2008; Meijer, de Groot, Van Boxtel, Van Gerven, & Jolles, 2006; Tun, O'Kane, & Wingfield, 2002; Tun & Wingfield, 1999).

One of the most frequently cited evidence for an age-related deficit in the *access function* is the finding of age differences in reading with distraction (Hasher, Lustig, & Zacks, 2007; Lustig & Hasher, 2001; Lustig, Hasher, & Zacks, 2007; Zacks & Hasher, 1994; Zacks et al., 2000). In the reading-with-distraction paradigm, each trial starts with a reading phase in which older and younger participants are required to read short texts (printed in italic font) while ignoring distractor words in a distinct font style (upright font), which are interspersed into the texts in the experimental conditions. Consistent with the predictions of inhibitory deficit theory, several studies reliably found that older adults were slowed down more by the distractor words than younger adults (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; Duchek, Balota, & Thessing, 1998; Dywan & Murphy, 1996; Kim, Hasher, & Zacks, 2007; Li, Hasher, Jonas, Rahhal, & May, 1998). In most of the experiments, each reading phase is followed by a multiple forced choice text comprehension test in which participants are required to identify previously read target words among new and previously ignored distractor words. Some studies found evidence for age differences in the disruption of text comprehension by distractors (Carlson et al., 1995; Kemper, McDowd, Metcalf, & Liu, 2008), but generally, the results of the multiple forced choice text comprehension test are highly unreliable (Connelly et al., 1991; Duchek et al., 1998; Dywan & Murphy, 1996; Feyereisen & Charlot, 2008; Kemper & McDowd, 2006; Mund, Bell, & Buchner, in press; Phillips & Lesperance, 2003), possibly due to the poor psychometric properties of this test (Darowski et al., 2008).

Thus, the conclusion that older adults are more impaired by the presence of distractor words when reading is primarily based on the finding of age differences in the slowing of reading due to the presence of distractor words. Unfortunately, the interpretation of this finding is also not without problems. Older adults are already slowed down in the control condition in which no distracting information is present. Thus, the age-related increase in reading times in the distractor conditions could be attributed to general cognitive slowing rather than to a problem with interference control. Most of the studies using the reading-with-distraction task (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Dywan & Murphy, 1996; Li et al., 1998) ignore this problem and fail to take general slowing into account when analyzing reading times (for exceptions, see Kim et al., 2007; Mund et al., in press).

A related problem of the classical reading-with-distraction task is that global reading time is a rather coarse measure of distractibility. Inhibitory deficit theory allows to derive the more specific prediction that older adults are slowed down because they spend more time looking at the distractor words than younger adults. Furthermore, older adults' reading times for the relevant target text should increase disproportionately in the distractor conditions because of the additional effort that is required to reconcile new information with distractor information previously encoded into working memory.

Two eye-tracking studies (Kemper & McDowd, 2006; Kemper et al., 2008) allowed for the measurement of reading times at the level of single words. Both studies provide little evidence for an age-related deficit in inhibitory control. For instance, the study of Kemper and McDowd yielded no evidence for age differences in eye fixations to distractor words. There were also no age differences in susceptibility to interference at the level of the global reading time. Older and younger adults were equally slowed down by the presence of distractor words. The interpretation of these results, however, is compromised by the fact that Kemper and colleagues modified the original reading-with-distraction paradigm by using single sentences in which they inserted single distractor words or phrases. This may have increased the predictability of the location of the distractors, which is known to decrease age differences in distractibility (Carlson et al., 1995; Li et al., 1998). The comparably small distractor-to-target ratio may also have decreased the likelihood of finding significant age differences in interference control. Finally, age differences in distractibility may be generally smaller when single sentences are used instead of full texts (see Phillips & Lesperance, 2003) because this procedure may distract participants from focusing on text comprehension, which may decrease interference by semantically related distractors.

In the present study, we used a procedure that was more similar to the original reading-with-distraction paradigm (e.g. Carlson et al., 1995; Connelly et al., 1991; Dywan & Murphy, 1996; Li et al., 1998) in that participants read whole texts in which large numbers of distractor words were inserted. Therefore, pronounced age differences in the increase in reading times due to the presentation of distractor words were to be expected according to inhibitory deficit theory. A difference between the present study and previous studies using the reading-with-distraction task is that we explicitly asked participants to focus on text comprehension. Note that a focus on text comprehension should maximize interference (and therefore, the probability of finding age differences in interference), given that text comprehension should be much more difficult when distracting information is present, especially if the distractor words are semantically related to the target text. As such, our experiment provides a sensitive test of inhibitory deficit theory. To measure reading time for target and distractor words separately, we used the moving-window method which has already been successfully applied to the examination of age differences in reading and text comprehension (Smiler, Gagne, & Stine-Morrow, 2003; Soederberg Miller, Stine-Morrow, Kirkorian, & Conroy, 2004; Stine-Morrow, Milinder, Pullara, & Herman, 2001; Stine-Morrow, Soederberg Miller, Gagne, & Hertzog, 2008). This method allowed us to test more specific hypotheses than most previous studies using the reading-with-distraction paradigm. Given that readers process each word as soon as it is encountered, the reading time for a word reflects the intensity with which it is processed (Just, Carpenter, & Woolley, 1982). If older adults process irrelevant material more intensely than younger adults, they should show a disproportionate increase in reading times for distractor words. Furthermore, we expected that reading of the target text would be slowed down in the distractor conditions. This increase in reading time should be more pronounced for older than for younger adults, because older adults should spend more time than younger adults trying to integrate distractor information into the mental representation of the target text.

Method

Participants

48 community-dwelling older adults and 49 younger adults attended the experiment proper. Three older adults were diagnosed with "mild cognitive impairment" in the dementia screening and thus were removed from data analysis. The remaining 45 older adults (35 women) ranged in age from 60 to 86 years (M = 67.67, SD = 5.80). The 49 younger adults (29 women) ranged in age from 18 to 30 years (M = 23.67, SD = 2.73). Younger adults had more years of education than older adults, $F(1,92) = 39.92$, $p < .01$, $\eta^2 = .30$, but older adults performed better on a vocabulary test (MWT-A; Lehrl, 1989) than younger adults, $F(1,92) = 12.25$, $p < .01$, $\eta^2 = .12$. Older adults had worse scores in the dementia screening test (DemTect; Kalbe et al., 2004) than younger adults $F(1,92) = 7.62$, $p = .01$, $\eta^2 = .08$, but the mean score of older adults (16.58 points) was well within the range of age-appropriate functioning (13 to 18 points). Older and younger adults did not differ with respect to their self-assessed overall contentment with life $\chi^2(1) = 0.91$, $p = .77$. All participants were native German speakers. Participants with a history of heart attack, stroke, brain trauma, alcoholism, Parkinson's disease, pulmonary emphysema

and those who had taken medication that could influence their cognitive functioning were excluded from the study.

Materials

Previous research (Mund et al., in press) has shown that it is possible that age differences in visual acuity may amplify age differences in the reading-with-distraction task. This problem must not be ignored. Thus, when assessing interference in the reading-with-distraction task, it is necessary to control for age differences in sensory capabilities. To this end, we used glasses with partial occlusion filters (Ryser Optik; St. Gallen, Switzerland) to artificially reduce younger participants' visual acuity. This method was successfully applied in previous cognitive-aging studies to equate visual acuity between younger and older adults (Lindenberger, Scherer, & Baltes, 2001; Mund et al., in press). There are several types of partial occlusion filters that reduce visual acuity to different degrees. To eliminate differences in visual acuity between the two age groups, younger participants were tested with filters that lowered their visual acuity to that of a (randomly) matched older adult. A computerized visual screening test (FrACT; Bach, 2007) was conducted before and after younger adult's visual acuity was adjusted. Visual acuity was assessed using the same (24 inch) computer monitor that was also used for the experiment proper. During the entire experiment, head position was fixed at a viewing distance of 110 cm to the computer screen using a chin rest and a forehead rest. This distance was necessary to measure visual acuity up to 1.07 Snellen decimals in the FrACT.

For the reading-with-distraction task, the same 20 dictation texts were used as in Mund et al.'s (in press) study. The texts were selected from school books used in seventh or eight grade, each containing 60 words. The texts comprised 5 sentences (SD = 1) and 25 propositions (SD = 3) on average. For three nouns of each text, two semantically related words were selected (e.g., *Dschungel* [jungle] and *Tropenwald* [tropical forest] were selected for *Regenwald* [rain forest]). One of these three alternatives was randomly selected for being used as an italicized target word that appeared at the correct position in the text. In the *related* distractor condition, one of the other two alternatives was randomly selected to be used as a distractor word, and the other was used as a control word for the analysis of the number of intrusions (see the *Procedure* section). In the *unrelated* distractor condition, the distractor words (and control words) were drawn from the five texts that were not selected for presentation. As in previous studies (Connelly et al., 1991; Kim et al., 2007), the target texts were presented in black italic *Courier* font (28 pt) on a white background. At the viewing distance of 110 cm, each character subtended about 0.29° vertically and 0.21° horizontally. For each participant, 15 out of the 20 texts were randomly selected to be used as target texts, with five texts being randomly assigned to one of the three distractor conditions (*continuous control, unrelated, related*). In the *continuous control* condition, the target texts were written continuously and contained no distractor words. In the conditions with distracting material, 30 distractor words (3 unique distractor words repeated 10 times) written in upright font were randomly interspersed into the target text with the only restriction that no distractor word followed another distractor word directly and that the first and the last word of the text were no distractor words. The texts were presented in random order.

Procedure

Participants were tested individually. The texts were presented using the moving-window method (Just et al., 1982). To familiarize participants with the task, two short sentences (one sentence with and one without distractor words) were presented. In a practice trial, participants read and recalled a text comprising *related* distractor words. The practice trial was followed by the 15 experimental trials. Each trial started with a blank screen. Upon a press on the space bar, dashed lines (the lengths of which corresponded to the to-be presented words) appeared along with punctuation to indicate the spacial configuration of the whole text. Each text started with an asterisk that was shown when participants first pressed the space bar. When participants pressed the space bar again, the asterisk was replaced with a dash and the first word of the text was presented. With each subsequent key press, the previously shown word was masked (by replacing its letters with dashes), and the next word was shown. In this way, the words of the text were successively revealed. The last word of a text was also followed by an asterisk, indicating the end of the text. Participants were instructed to press the space bar with the index finger of the dominant hand. Instructions emphasized text comprehension. The participants were told to read the italicized texts quietly at a comfortable pace, and not to make any pauses. They knew that they would have to ignore all distractor words printed in upright font.

The reading phase was followed by a free recall test. We used a free recall test instead of the multiple forced choice recognition test (used in previous studies; Carlson et al., 1995; Connelly et al., 1991; Duchek et al., 1998; Dywan & Murphy, 1996; Mund et al., in press) because it provides a more reliable and more valid measurement of text comprehension (Mund, Bell, & Buchner, 2010). The free recall test started with a question mark appearing in the middle of the screen. This was the signal for participants to recall the target text with as many details as possible. Participants' answers were recorded by the computer's built-in microphone for later transcription and scoring. When participants felt that they could not remember any more details, they pressed the space bar to initiate the next trial.

For scoring purposes, we performed a propositional analysis on the texts using the system of Turner and Greene (1987) that is based on the text-comprehension model of Kintsch and van Dijk (1978). Participants' answers were transcribed and compared to the template text bases using a gist-based scoring criterion. Thus, propositions comprising synonyms of to-be recalled words were scored correct. To increase the reliability and validity of the scoring procedure, we used the *Projekt Deutscher Wortschatz* database (http://wortschatz.uni-leipzig.de/) to identify synonyms. The database is based on a huge collection of texts from various sources (e.g., newspaper articles, webpages) and thus represents a large portion of current-day word usage (see Biemann, Bordag, Heyer, Quasthoff, & Wolff, 2004). To evaluate the reliability of the propositional scoring procedure, the 90 recall protocols of six randomly selected participants (3 younger and 3 older adults) were scored by an independent rater. Inter-rater agreement, as assessed by the kappa-coefficient (Cohen, 1960), was $\varkappa = .93$ (i.e., "almost perfect" Landis & Koch, 1977).

To detect distractor intrusions, the words of the recall protocols were automatically compared to the word stems of the distractor words and the control words using a computer program. If a word in the recall protocol matched the word stem of a distractor word, the word was scored as an intrusion. However, not all distractor intrusions may be due to aftereffects of distractor presentation. For instance, in the *related* distractor condition, participants may paraphrase and add new information that may coincidentally match the distractor words. To control for spontaneous use of distractor words, we also analyzed intrusions from control words that were not presented as distractors. In both distractor conditions, it was randomly determined whether a specific word would be used as a distractor or as a control word. Therefore, differences in the rate of intrusions between these two types of words can only be attributed to aftereffects of distractor word presentation in the reading phase.

Design

A 2 × 3 design was used with group (*younger* vs. *older*) as a between-subject factor and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as a within-subject factor. The dependent variables were the reading times, the proportion of correctly recalled propositions, and the number of intrusion errors. Given a sample size of 94 and assuming a correlation of $\rho = .5$ among the levels of the within-subject factor, an effect of size $f = 0.17$ (i.e., between small and medium effects as defined by Cohen, 1988) could be detected for the interaction between group and distractor condition with a probability of $1 - \beta = .95$ (Faul, Erdfelder, Lang, & Buchner, 2007).

Results

Treatment check of the visual acuity manipulation

When younger adults were tested *without* partial occlusion filters before visual acuity adjustment, visual acuity was worse for older ($Md = 0.80$) than for younger adults ($Md = 1.07$), $z = -6.42$, $p < .01$. When younger adults were tested *with* partial occlusion filters, visual acuity was the same for older ($Md = 0.83$) and younger adults ($Md = 0.79$), $z = -0.32$, $p = .75$, confirming that we succeeded in equating visual acuity between older and younger adults.

Reading times

Given that previous studies using the reading-with-distraction paradigm did not allow for a separate measurement of reading times for target and distractor words, the conclusions of these studies are based on the analysis of the total-text reading times (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Duchek et al., 1998; Dywan & Murphy, 1996; Kim et al., 2007; Li et al., 1998; Mund et al., in press). To allow for a comparison of these results with those of the present study, we start by reporting the analysis of the total-text reading times. A 2 × 3 repeated-measures MANOVA with age group (*younger* vs. *older*) and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables revealed significant main effects of age group, $F(1,92) = 30.67$, $p < .01$, $\eta^2 = .25$, and distractor condition, $F(2,91) = 367.39$, $p < .01$, $\eta^2 = .89$. As was to be expected, older adults read slower than younger adults. Furthermore, reading times were slower in the distractor conditions than in the control condition. The interaction between age group and distractor condition was also significant, $F(2,91) = 7.45$, $p < .01$, $\eta^2 = .14$. Older adults were slowed down more by irrelevant information than younger adults (Figure 1). So far, the results perfectly replicate those obtained in previous studies (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Duchek et al., 1998; Dywan & Murphy, 1996; Kim et al., 2007; Li et al., 1998; Mund et al., in press). This finding has been repeatedly accepted as evidence for a general decline of inhibitory control in old age.

The moving-window method applied in the present study allows us to go one step further and to analyze reading times for target and distractor words separately. First, we analyzed reading times for the target words (Figure 2, upper panel) to examine whether older adults' reading of target words would be disproportionally slowed by the presence of distractor information. A 2 × 3 MANOVA revealed significant main effects of age group, $F(1,92) = 26.28$, $p < .01$, $\eta^2 = .22$,—older adults read the target words more slowly than younger adults—and distractor condition, $F(2,91) = 8.45$, $p < .01$, $\eta^2 = .16$. Specifically, reading of target words was slowed down in the distractor conditions compared to the control condition, $F(1,92) = 17.08$, $p < .01$, $\eta^2 = .16$, and the distractor conditions did not differ from each other, $F(1,92) = 0.02$, $p = .90$, $\eta^2 < .01$. Most importantly, there was no interaction between age group and distractor condition, $F(2,91) = 0.71$, $p = .50$, $\eta^2 = .02$. Thus, the increase in reading times for target words in the distractor conditions was the same for older and younger adults. This refutes the hypothesis derived from inhibitory deficit theory that older adults should spend more time looking at the target text when the text comprises distracting information.

Next, we analyzed reading times for the distractor words to see whether older adults spend more time looking at distractor words than younger adults (Figure 2, center panel). A 2 × 2 MANOVA showed that older adults spent significantly more time looking at distractor words than younger adults, *F*(1,92) = 39.02, $p < .01$, $\eta^2 = .30$, and that participants looked longer at related distractor words than at unrelated distractor words, *F*(1,92) = 16.05, $p < .01$, $\eta^2 = .15$, but there was no interaction between age group and distractor condition, *F*(1,92) = 1.58, $p = .21$, $\eta^2 = .02$. At first glance, one might be tempted to attribute the age difference in distractor word reading time to a more intense processing of distractor information in old age due to a deficit in inhibitory control. However, we know from the previous analyses that older adults read more slowly in general than younger adults. Therefore, the finding of longer reading times for distractor words in older adults is not surprising. It is more surprising that age differences in reading times for distractor words are comparatively small. At a descriptive level, the age differences in reading times for distractor words (271 ms; a 36.4% increase of reading times of the older participants over that of the younger participants) were much less pronounced than the age differences in reading times for target words in the control condition (417 ms; a 50.9% increase of reading times of the older participants over that of the younger participants). Furthermore, note that both older and younger adults spent much less time looking at distractor words than looking at target words, suggesting that both age groups seem to be able to discriminate between target and distractor words, and to stop processing of the distractor information. If cognitive aging was primarily characterized by a problem with inhibitory control, we would expect that age differences are most pronounced for the reading times of the distractor words. However, the results are clearly inconsistent with the assumption that older adults spend *disproportionally* more time looking at distractor words than younger adults.

Given that the two previous analyses of reading times at the level of single words showed no evidence for an age-related deficit in inhibitory control, we conclude that the interaction between age group and distractor condition for the total-text reading times can be simply attributed to general slowing. This assumption was confirmed by an analysis of the mean reading time per word (i.e., the total-text reading time divided by the number of words presented; Figure 2, lower panel). A 2 × 3 MANOVA revealed a main effect of age group, *F*(1,92) = 30.35, $p < .01$, $\eta^2 = .25$, showing that older adults were slower than younger adults. The main effect of distractor condition was not significant, *F*(2,91) = 1.87, $p = .16$, $\eta^2 = .04$. There was no interaction between age group and distractor condition, *F*(2,91) = 1.53,

$p = .22$, $\eta^2 = .03$. This finding suggests that there is no age-related increase in reading times in the distractor conditions at all. The interaction between age group and reading time that was obtained in the analysis of the total-text reading times (that was previously interpreted as an evidence for age-related inhibitory decline, see Hasher et al., 2007; Lustig & Hasher, 2001; Lustig et al., 2007; Zacks & Hasher, 1994; Zacks et al., 2000) seems to be solely due to older adults being generally somewhat slower than younger adults.

The within-trial modulation of distraction

We also analyzed the pattern of reading times across the 10 repetitions of each distractor word in a text to see whether this analysis would reveal evidence for age differences in the processing of distractor information. We suspected that reading times for distractor words would decrease with repetition because participants would adapt to the repeated presentation of the distractors. This distractor repetition effect might be stronger for younger than for older adults. This hypothesis was based on the results of McDowd and Filion (1992), who had found that both younger and older adults showed an initial orienting response to novel auditory distractors, but younger adults habituated more quickly to the distractors than older adults. Figure 3 shows the reading times of distractor words as a function of distractor condition and repetition. These data were analyzed using a 2 × 2 × 10 MANOVA with age group (*older* vs. *younger*), distractor condition (*unrelated* vs. *related*), and distractor repetition (1 to 10) as independent variables. In both age groups, reading times of unrelated and related distractor words decreased as a function of distractor repetition, $F(9,84) = 11.18$, $p < .01$, $\eta^2 = .55$. This finding suggests that the efficiency with which the distractors can be rejected improves with repetition. It seems that both younger and older participants got used to the distractor word and learned to reject the distractor word more quickly. The decrease in reading times for distractor words did not differ between younger and older adults, $F(9,84) = 0.73$, $p = .69$, $\eta^2 = .07$. This finding corroborates the conclusion drawn from the previous analyses that the processing of distractor information does not differ between younger and older adults.

A similar analysis was performed on the reading times for the target words. The target text was subdivided into ten consecutive text segments, each consisting of six words. Reading times for the target segments were analyzed using a 2 × 3 × 10 MANOVA with age group (*older* vs. *younger*), distractor condition (*continuous control* vs. *unrelated* vs. *related*), and text segment (1 to 10) as independent variables. There were main effects of age group, $F(1,92) = 26.28$, $p < .01$, $\eta^2 = .22$, distractor condition, $F(2,92) = 8.46$, $p < .01$, $\eta^2 = .16$, and text segment, $F(9,84) = 14.36$, $p < .01$, $\eta^2 = .61$. Figure 4 shows that reading time for the first target text segment was comparatively fast, probably reflecting the fact that working memory load is relatively small at the beginning of the text. Reading times for target words slowed down across the first text segments, probably reflecting an increase in working-memory load as a function of the increased number of semantic concepts that had to be integrated into the mental representation of the target text (Haberlandt & Graesser, 1989; Stine-Morrow et al., 2001). The subsequent increase in reading speed can be explained by assuming that the reading process gets more efficient when the readers can use their knowledge about the gist of the text to facilitate the integration of new information (Soederberg Miller et al., 2004; Stine-Morrow et al., 2008). At the end of the text, participants are known to recapitulate the text content before the recall phase (Haberlandt, Berian, & Sandson, 1980), resulting in a pronounced increase in reading time (Haberlandt & Graesser, 1985; Just et al., 1982). Thus, reading times for the target words show a markedly different course than reading times of the distractor words, showing that the decrease in reading times for distractor words cannot be simply attributed to a general decrease of reading times during the course of a single trial. There was a significant interaction between distractor condition and text segment, $F(18,75) = 2.62$, $p < .01$, $\eta^2 = .39$. The difference in reading times between the distractor conditions and the control conditions is most pronounced in the first half of the text and is markedly reduced in the second half of the text. This suggests that the influence of the distractor information on text comprehension decreases, consistent with the finding that the efficiency with which the distractors can be rejected increases with distractor repetition. Yet again there was no evidence that the distraction effect differed between younger and older adults in that there was no three-way interaction between age group, distractor condition, and text segment, $F(18,75) = 1.36$, $p = .18$, $\eta^2 = .25$. Further evidence against the assumption of age differences in distractibility in the processing of distractor information derives from the fact that there were no age differences in the increase of reading times at the end of the text that can be explained in terms of an intensive recapitulation process that serves to organize and integrate the mental representation of the whole target text before recall. A priori, one could have expected that this recapitulation process would be especially slowed down in older adults trying to reconcile distractor information with the mental representation of the target text, but there is no indication for such an age difference even at a descriptive level.

Recall performance

Next, we analyzed performance in the free-recall test. The proportion of correctly recalled propositions was analyzed using a 2 × 3 MANOVA with age group (*younger* vs. *older*) and distractor condition (*continuous control* vs. *unrelated* vs. *related*) as independent variables (Table 1). Older adults recalled fewer propositions than younger adults, $F(1,92) = 22.10$, $p < .01$, $\eta^2 = .19$, but there was neither a main effect of distractor condition, $F(2,91) = 0.34$, $p = .97$, $\eta^2 < .01$ nor a significant interaction between age group and distractor condition, $F(2,91) = 2.43$, $p = .09$, $\eta^2 = .05$. This suggests that older adults' comprehension of the target text (and subsequent recall of this text) was not affected by the presence of distractor words. This finding refutes the hypothesis derived from inhibitory deficit theory that older adults' text comprehension would suffer when distracting information is present.

The analysis of the intrusion errors showed that older adults made more intrusions from related distractor words than younger adults, $F(1,92) = 17.58$, $p < .01$, $\eta^2 = .16$ (Table 2). Given that there were no age differences in the number of intrusions from semantically related control words, $F(1,92) = 1.88$, $p = .17$, $\eta^2 = .02$, this finding cannot simply be attributed to older adults paraphrasing more than younger adults. Unrelated distractor words were reproduced less frequently (Table 2). Nevertheless, the same data pattern was found for unrelated distractor words as for related distractor words. Older adults reproduced more unrelated distractor words than younger adults, $F(1,92) = 7.90$, $p = .01$, $\eta^2 = .08$, and there was no age difference in the number of intrusions from unrelated control words, $F(1,92) = 2.11$, $p = .15$, $\eta^2 = .02$. These results are consistent with findings of Mund et al. (2010), who found equally large age differences in the number of intrusions from distractor words.

Discussion

The present study provides more detailed insights into the reading-with-distraction paradigm than most previous studies. The analysis of total-text reading times replicated previous findings (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Duchek et al., 1998; Dywan & Murphy, 1996; Kim et al., 2007; Li et al., 1998; Mund et al., in press) that older adults were slowed down by the presence of distractor words to a larger degree than younger adults. In the past, this finding was widely accepted as empirical evidence in favor of the assumption that older adults suffer from a general deficit in inhibitory attention (Hasher et al., 2007; Lustig & Hasher, 2001; Lustig et al., 2007; Zacks & Hasher, 1994; Zacks et al., 2000). In the present study, we extended the reading-with-distraction paradigm, using the moving-window-method to examine reading times at the level of single words. This allowed for a more fine-grained analysis of the reading times in the reading-with-distraction paradigm. Most importantly, reading times for distractor words and target words were analyzed separately. The results of these analyses showed that at the level of reading individual words, older and younger adults were equally slowed down by the presence of distractor material, suggesting that there were no age differences in the disruption of online text processing. This interpretation was corroborated by the analysis of propositional recall that yielded no evidence for the assumption that older adults' text comprehension, or subsequent memory for the texts, was impaired by the presence of distractor material. Older adults took somewhat more time than younger adults to process distractor words, but this age difference was rather small and can be attributed to general slowing. When the mean reading time per word was analyzed (i.e., the total-text reading time divided by the number of words presented), there was no evidence for disproportional age-related slowing in the distractor conditions at all. The more pronounced increase in older adults' reading times in the distractor conditions was thus most likely due to general cognitive slowing and not due to specific age-related problems with interference control. There were also no age differences in the decrease of the distraction effect during the course of each trial.

These results are clearly inconsistent with the predictions derived from inhibitory deficit theory. Furthermore, this pattern of results suggests that the evidence for an age-related increase in distractibility in the reading-with-distraction paradigm obtained in previous studies should be interpreted with extreme caution because most of these studies (Carlson et al., 1995; Connelly et al., 1991; Darowski et al., 2008; Duchek et al., 1998; Dywan & Murphy, 1996) failed to take general slowing into account.

The present results are largely consistent with the findings of Kemper and McDowd (2006), who found no evidence for an age-related inhibitory deficit in the reading-with-distraction paradigm using eye-tracking technology. Older adults did not spend more time fixating distractors than younger adults, and there was also little evidence for age differences in online processing of target text in the presence of distracting information. In the introduction, we have explicated that these null findings could also be attributed to the fact that Kemper and McDowd used a modified reading-with-distraction paradigm that may be less sensitive to age differences in susceptibility to interference. In the present study, in contrast, we maximized the likelihood of finding significant age differences in interference by using unpredictable distractor locations, a higher distractor-to-target ratio, longer texts, and instructions that focused on text comprehension. Although inhibitory deficit theory clearly predicts large age differences in interference under these conditions, we found evidence against age differences in the disruption of online text processing by distractor words.

This is not to say that age differences in selective attention do not occur at all. In the reading-with-distraction paradigm, there is some evidence suggesting that older adults are less able than younger to stop the vocalization of the distractor words when reading texts with distractors aloud (Connelly et al., 1991; Dywan & Murphy, 1996)[1]. Furthermore, in the present study, older participants were more likely than younger adults to make intrusions from the to-be ignored material when trying to recall the target texts. It is interesting that these age differences in memory occurred even though there is no evidence for age differences in online processing of distractor information. This is consistent with other studies showing that voicing of the distractor words did not predict the number of memory intrusions (Connelly et al., 1991; Dywan & Murphy, 1996). According to Dywan and Murphy, the age differences in distractor intrusions can be attributed to older adults' problems with remembering the source of the distractor information rather than to age differences in online distractor processing.

The conclusion that has to be drawn from these findings is that there is no general deficit in inhibitory attention that leads to a general age-related increase in the susceptibility to interference. Instead, cognitive aging is characterized by well defined deficits in specific functions of interference control. This fits with other research suggesting that inhibition is not a unified construct (Kramer, Humphrey, Larish, & Logan, 1994), with age differences in some functions associated with interference control (e.g., Bell et al., 2008; Titz & Verhaeghen, 2010), but not in others (e.g., Bell & Buchner, 2007; Murphy, McDowd, & Wilcox, 1999; Van Gerven, Meijer, Vermeeren, Vuurman, & Jolles, 2007; Verhaeghen & De Meersman, 1998). The present results extend these findings by showing that the assumption of a general deficit in inhibitory attentional control in old age does not provide a satisfactory account of the pattern of age differences in the reading-with-distraction task. This is particularly interesting because the age differences in this paradigm have been repeatedly cited as a key finding supporting inhibitory deficit theory. This situation is strikingly parallel to the state of affaires in the negative priming paradigm, which has also been cited as primary evidence for a general age-related deficit in inhibitory attention (Connelly & Hasher, 1993; Hasher, Stoltzfus, Zacks, & Rypma, 1991) before a number of studies showed age-related stability in the size of the negative-priming effect (e.g., Buchner & Mayr, 2004; Gamboz, Russo, & Fox, 2002).

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Footnotes

[1] This was also confirmed by a reanalysis of the results of Mund et al. (in press), which also showed that older adults were more likely than younger adults to start articulating the distractor words.

Author Notes

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Table 1

Proportion of correctly recalled propositions as a function of age group and distractor condition. The numbers in parentheses represent the standard errors of the means.

Distractor Condition	Age Group	
	Younger Adults	Older Adults
Continuous Control	35.33 (1.91)	25.83 (1.99)
Unrelated	36.45 (2.01)	24.18 (2.10)
Related	37.62 (1.94)	23.44 (2.03)

Table 2

Number of intrusion errors as a function of group, distractor condition, and error type. The numbers in parentheses represent the standard errors of the means.

Distractor Condition	Error Type	Age Group	
		Younger Adults	Older Adults
Related	Distractor Words	2.84 (0.34)	4.91 (0.36)
	Control Words	1.08 (0.16)	0.76 (0.17)
Unrelated	Distractor Words	0.31 (0.15)	0.91 (0.15)
	Control Words	0.14 (0.05)	0.04 (0.05)

Figure Captions

Figure 1: Mean total-text reading time as a function of age group, and distractor condition. The error bars represent the standard errors of the means.

Figure 2: Mean reading time per word as a function of age group, distractor condition, and word type. Upper panel: Mean reading times for target words. Middle panel: Mean reading times for distractor words. Lower panel: Mean reading time per word (i.e., the total-text reading times divided by the number of words presented). The error bars represent the standard errors of the means.

Figure 3: Mean reading times for distractor words as a function of age group, distractor condition, and repetition. Left panel: Mean reading times for unrelated distractor words. Right panel: Mean reading times for related distractor words. The error bars represent the standard errors of the means.

Figure 4: Mean reading times for target words as a function of age group, distractor condition, and text segment. The error bars represent the standard errors of the means.

Figure 1

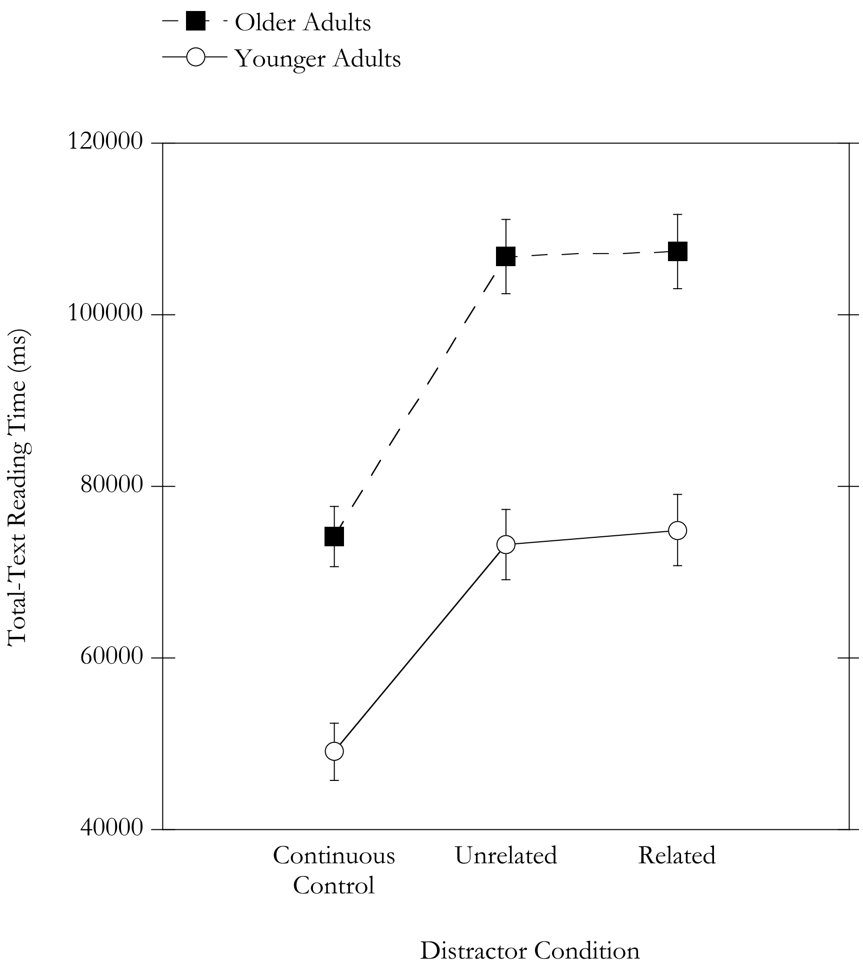

Older Adults
Younger Adults
120000
100000
80000
60000
40000
Total-Text Reading Time (ms)
Continuous
Control
Unrelated
Related
Distractor Condition

Figure 2

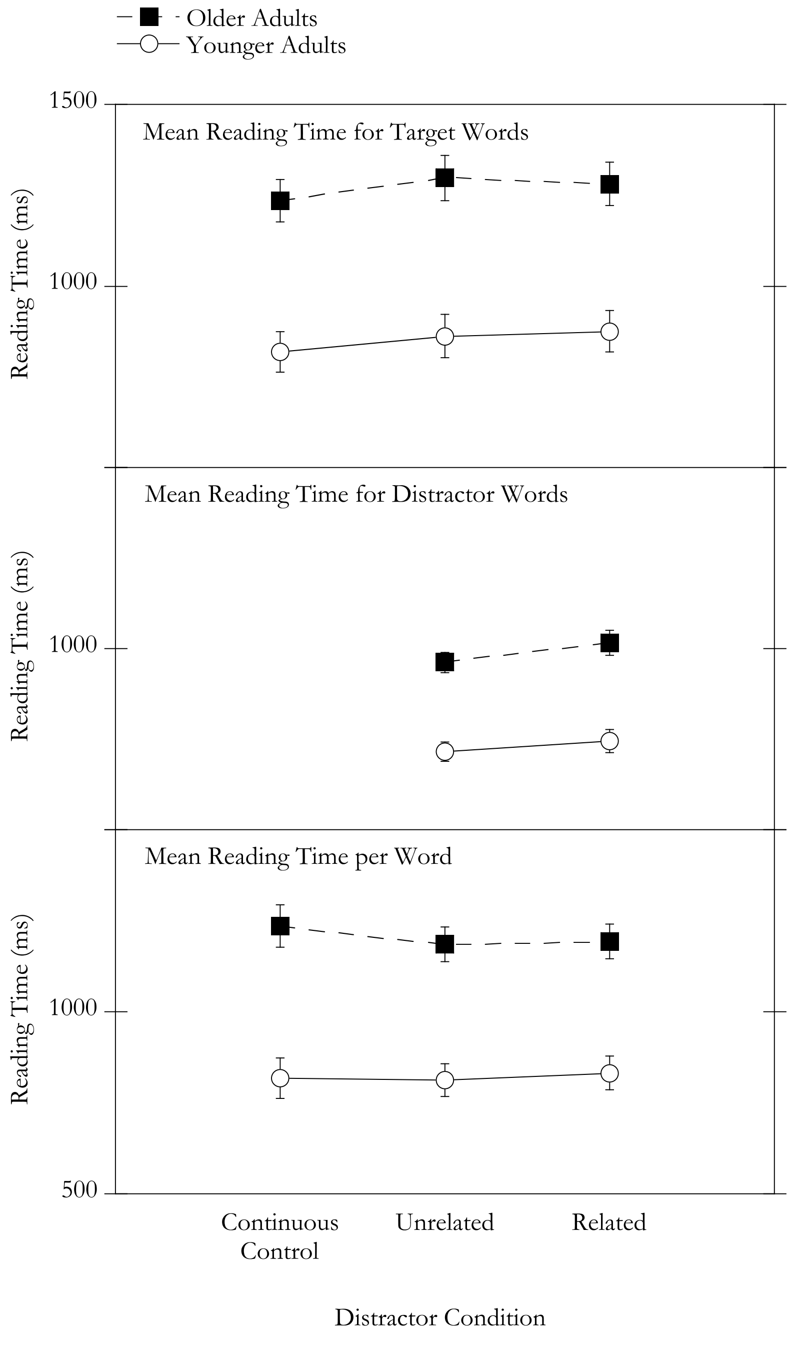

Older Adults
Younger Adults
1500
1000
500
Reading Time (ms)
Mean Reading Time for Target Words
Reading Time (ms)
1000
Mean Reading Time for Distractor Words
Reading Time (ms)
1000
Mean Reading Time per Word
Continuous Control
Unrelated
Related
Distractor Condition

Figure 3

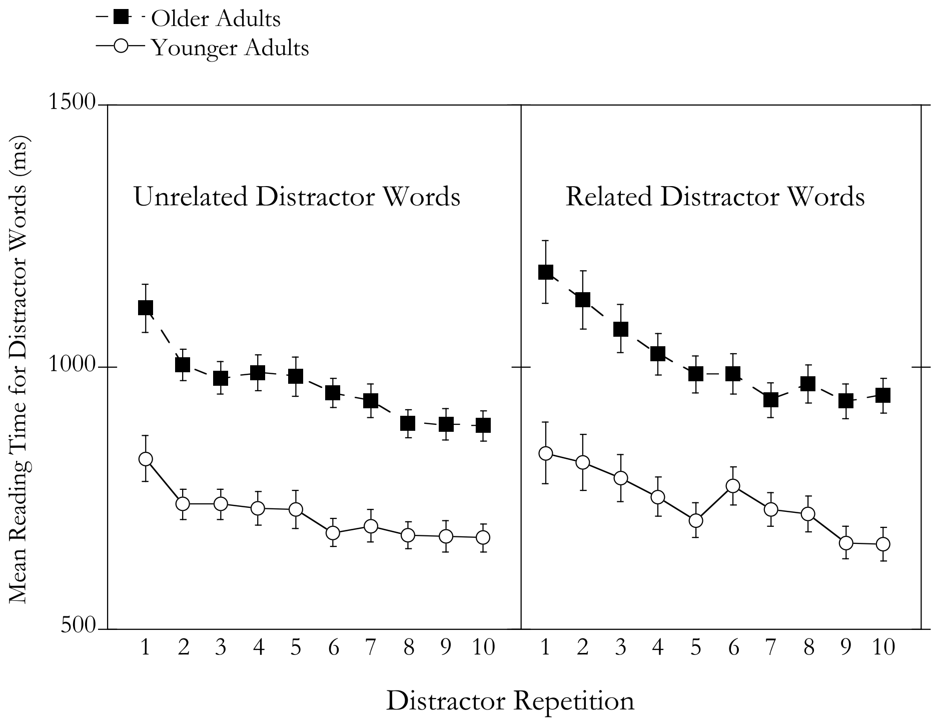
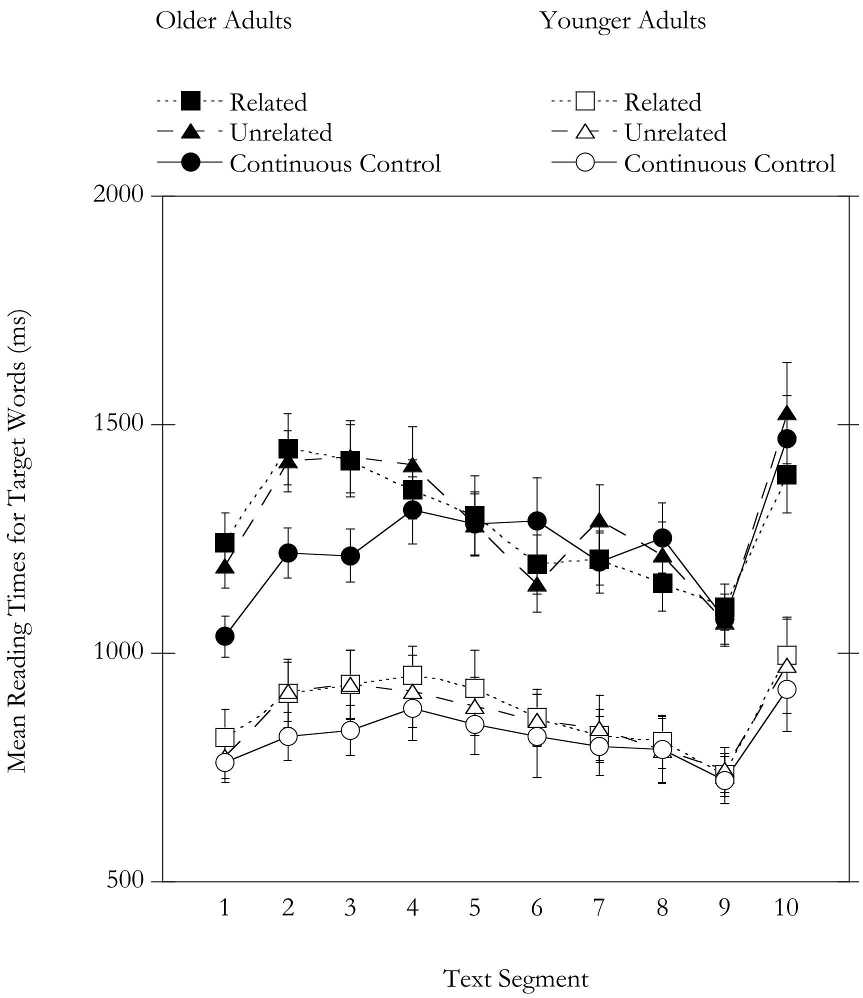

Older Adults
Younger Adults
1500
1000
500
Mean Reading Time for Distractor Words (ms)
Unrelated Distractor Words
Related Distractor Words
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
Distractor Repetition

Figure 4


Older Adults
Younger Adults
Related
Unrelated
Continuous Control
Related
Unrelated
Continuous Control
2000
1500
1000
500
Mean Reading Times for Target Words (ms)
1
2
3
4
5
6
7
8
9
10
Text Segment

Danksagung

Mein größter Dank gilt Herrn Prof. Dr. Axel Buchner. Ohne seine außerordentliche Unterstützung wäre die Verfassung dieser Arbeit nicht möglich gewesen. Ich danke auch Herrn Prof. Dr. Jochen Musch für die Übernahme der Zweitbegutachtung. Allen Kolleginnen und Kollegen unserer Abteilung ein riesiges Dankeschön für den Rückhalt und für die schöne gemeinsame Zeit. Insbesondere aber möchte ich Herrn Dr. Raoul Bell für die großartige Zusammenarbeit während der letzten Jahre danken. Drohende Nervenzusammenbrüche wurden stets fachmännisch abgewendet und sowohl Bürotür als auch Ohren standen immer für meine Probleme offen. Ohne sein überwältigendes Engagement und sein enormes Fachwissen wäre die vorliegende Arbeit in dieser Form sicherlich nicht entstanden.

Des Weiteren konnte ich jederzeit auf die Hilfe von (Hello) Trang (Kitty) zählen, die mich nicht nur mit gespitzten Bambusstäbchen zu Höchstleistungen angespornt hat, sondern die zudem mit der Verleihung zahlreicher Titel über iChat für so manchen Lachanfall in meinem Büro sorgte. Auch durfte ich unzählige Male auf die Expertise meiner ehemaligen Bürogenossin Sandra zurückgreifen. Sie unterrichtete mich nicht nur in der effizienten Verwendung von Heftgeräten oder von diversen Computerprogrammen, sondern war vor allem eine wunderbare Weggefährtin. Liebe Grüße ins „Exil“!

Mit ganzem Herzen möchte ich mich auch bei meinen Eltern bedanken. Sie haben eine Engelsgeduld bewiesen und einen unermüdlichen Glauben daran, dass ich auch diese berufliche Hürde meistern würde. Immer wieder haben sie die richtigen aufbauenden Worte gefunden. Ihr seid die besten „Püschologen“ (gell, Papa!). Besondere Anerkennung verdienen darüber hinaus die Aufmunterungsstrategien meiner Freunde, insbesondere Rahwa, Helen (Kaffee?!?), Jan-Henryk und Berna. Bernd, Lars und Mario möchte ich zudem für die Toleranz in (diesen) „Harte(n) Zeiten“ danken. Insbesondere Mario (meinem Zottel!) sollte ein Orden verliehen werden. Das Chaos in Wohnung und Kopf während der letzten Wochen wurde wohlwollend ignoriert und mir wurde in sämtlichen Belangen der Rücken freigehalten. Typisch L-HEP (Lebens-Helfer Einer Püschologin)! Danke euch allen, dass ihr mich auf diesem langen Weg begleitet habt!