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The Time Course of Automatic Lexical Access and Aging

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This study addresses the issue of cognitive slowing in the elderly by examining the time course of automatic lexical access. College-aged subjects typically show a brief rise time (300-500 msec) for lexical access. In the present study, we examine whether there are changes in rapid, automatized access routines with age. Elderly and college-aged subjects performed a lexical decision task wherein semantically related words embedded in a continuous list were presented one at a time with a varying (300-1500 msec) inter-word interval. The use of a continuous list, a repeated word, and a very short inter-stimulus interval allowed automatic lexical access to be straightforwardly examined. The elderly subjects showed an onset of automatic lexical access that was similar in time frame to that for college-age subjects. These findings suggest that wherever the locus of age-related slowing

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may he, it is not in the early, language-specific processing devices that mediate lexical access.

There is a large body of research that concentrates on the changes in language performance as a result of normal aging. One of the conclusions of this research is that proficiency in language diminishes in older adults due in part to what has been termed "slowing," (e.g., Birren, Woods, & Williams, 1980; Hertzog, Raskind, & Cannon, 1986; Salthouse, 1982). Yet, the functional locus and range of "age-related slowing" remain, unclear. In this paper we seek to examine the issue of "slowing" by examining the time course of lexical access in the elderly, and we seek more generally to use the results of this research to advance some aspects of our understanding of the biological resources of language processing.

Our study turns on a lexical priming paradigm wherein the processing of a visually presented word is facilitated by having just seen (or heard) another meaningfully related word (e.g., the prime "table" facilitates the processing of the target word "chair"). This facilitation is most usually shown in one of two ways: by an increase in the speed with which the target word is named or by an increase in the speed with which the target word is recognized in a lexical decision task. The faster naming or recognition time for the second word is taken as an indication that the meaning of the first word was activated and that, in consequence, the threshold was lowered (at least briefly) for naming and recognition of all words within its semantic sphere.

Two Processing Modes

There appear to be two distinct processing modes by which such priming can be affected, each with its own distinct time course. Our goal is to map out those time courses in elderly and college-aged populations.

One processing mode is popularly termed "controlled processing." By definition, controlled processing places demands on attentional processes and can be affected by the employment of strategies (e.g., Posner & Snyder, 1975). Controlled effects are seen in lexical retrieval processes, for example, when expectancies. are built up because a large proportion of successive stimuli bear meaningful relations (e.g., denHeyer, Briand, & Dannenbring, 1983). In effect, controlled processes appear to come into play when the subject *actively* looks for relations between words, that is, when the observance is under conscious control. For college-age populations, controlled processes do not show an effect on lexical processing until roughly 500-700 msec post-lexical entry (e.g., Neely, 1977).

By contrast, the other mode of processing that affects lexical priming, referred to as "automatic processing", is by definition *not* under the subject's control. Automatic processes do *not* place a load on attention and *cannot* be affected by intentional control. Specifically with respect to lexical processes, automatic access is fast-acting. There is a strict temporal course associated with automatic priming effects; these effects occur (for college-age populations) within the finite range of 300 to 700 msec following the presentation of a prime (with some variability depending on specific task elements) and then rapidly diminish (see, e.g., Prather & Swinney, 1988). In effect, it appears that automatic effects diminish to a negligible amount by 1100 msec, so that by 1100 msec past-prime, any measurable priming effects are attributable to controlled processes. Also, these automatic processes act as if they were mandatory: their operation is not responsive to any kind of rational considerations or external influences (see, e.g., Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). So, for example, there appears to be an unalterable activation of all of a polysemous word's meanings during automatic lexical access, regardless of contextual factors. Specifically, in this respect, it has been shown that exhaustive priming occurs for all of a polysemous word's meanings, even when a prior sentence context clearly indicates the relevance of only one of its meanings. (Simpson, 1981; Swinney, 1979). Within 1000 msec, however, priming for the contextually irrelevant meaning is diminished essentially to a baseline level (Onifer & Swinney, 1981; Tanenhaus et al., 1979).

An important reflection of this automatic, exhaustive search is the order in which the multiple meanings of a polysemous word are retrieved. Namely, it has been shown that the meanings are ordered in lexical access in relation to their frequency of occurrence, moving from the most to the least frequent (Onifer & Swinney, 1981; Simpson, 1981). So, for example, given the word "bank," priming is shown more quickly for "money" (a word reflecting "bank's" most frequent or primary meaning) than for "river" (a word reflecting "bank's" least frequent or secondary meaning). However, while slower, the secondary meaning is still always automatically primed by the target, at least briefly.

Experimental Paradigms

A priming paradigm that in its typical application is best suited to examination of controlled, strategy-based lexical processing is the traditional "pairs paradigm." In this task, subjects are usually asked to read passively the prime word in a pair and then make a lexical decision about or read aloud the target word that follows it. Or they may be shown two words simultaneously and asked to decide whether both are real English words (e.g., Meyer, Schvaneveldt, & Ruddy, 1975). There are a number of reasons why the pairs paradigm is prone to elicit strategies and expectations of relatedness among words and thereby to allow or even encourage controlled processing. First, there is typically a delay between paired test items, and setting the pairs apart (or presenting the members of the pair simultaneously) suggests that the words somehow belong together, even if the task instructions are neutral in this respect. Second, there is time after the presentation of each pair to reflect upon the connection between the paired words just viewed.

The pair-priming technique is not inherently inflexible with regard to the processing mode that it taps, however. Neely (1977), for example, introduced a variation on that paradigm that allowed separate examination of the time course of both automatic and controlled processes. Specifically, college-age students were instructed that following the prime word BODY, they could expect a building part (e.g., BODY-door) as the target item. That expectation typically was met, but occasionally, rather than the expected unrelated association (e.g, BODY-door), subjects were unexpectedly presented with associatively related pairs (e.g., BODY-arm). When the time between the prime and target was longer than 400 msec, subjects were able to use the "expectancy" instructions to their advantage, thus showing a priming effect when their expectations were met. By contrast, if the target was presented within 400 msec of the prime, then, the expected category relations had no bearing on the priming patterns; rather, priming was seen only for associatively related pairs. These findings suggest that time and attention were necessary in order to have expectancy influence lexical decisions and that when time was insufficient to deploy attention, expectations bore no effect. Thus, Neelys paradigm allowed a mapping of the time post-lexical onset at which automatic associative priming began (between 250 and 400 msec) and the time at which intentional processing began to contribute to overall facilitation effects.

By telling subjects to look for particular *nonassociative* relations, Neely's paradigm distracted them from intentionally looking for *associative* relations. Under those constraints, when controlled and associative effects were in competition, subjects' attention to expected relations inhibited any automatic associative priming effects. Neely's paradigm did not, however, allow mapping of automatic and controlled processes independently of each other. To do so, Prather and colleagues (see Prather & Swinney, 1988) developed another modification of the traditional priming paradigm, one in which words were presented in continuous lists rather than as discrete pairs. In this task, words are presented at regular intervals with a consistent delay between words, (e.g., in one version, words are on the screen for 750 msec, with a 500-msec delay between words, such that a new word appears every 1250 msec). Subjects respond to every word, i.e., to prime as well as target words. Since the subject is responding to a continuously running list of stimuli, which only occasionally has one word followed by an associatively related word, it is difficult for subjects to notice (and therefore to anticipate) connections between words. Further, subjects are literally too busy with the continuous responding to invoke intentional strategies, particularly at short (e.g., <700 msec) interstimulus intervals (ISIs). As the ISI lengthens, it becomes at least possible for subjects to invoke strategies. To minimize strategic processes, Prather et al. included a predictable pattern that could attract subjects' attention much more readily than the occasional associatively related pairs. Specifically, one word was repeated at irregular intervals (the word "WORD" was presented on average every 15th word). By including that repeated word, subjects developed expectations about the appearance of that word and were therefore distracted from developing strategies specific to the appearance of associatively related words. In that way, Prather et al. were able to map out the rise and fall of automatic priming effects in college-age populations, independently of any effects of controlled processes. Their basic finding was that priming effects rose relatively rapidly, peaking at 500 msec, and then diminished with no priming evident by 1100 msec.

Previous Findings and the Present Effort

With one exception, previous investigations concerned with lexical and semantic access in the aging adult have not stayed within the temporal and experimental parameters that we have described. Consequently these studies have not adequately separated the ranges of automatic and controlled processing. Studies where words were presented in pairs (Chiarello, Church, & Hoyer, 1985; Howard, McAndrews, & Lasaga, 1981) or where instructions directed subjects to expect a relation between the words in a pair (Howard, Shaw, & Heisey, 1986) promoted the development of attentional/controlled strategies, thereby disallowing strong claims about automatic processing.

The one study that used paired presentations and that did seek to disentangle automatic and controlled processing was unable to do so. Burke, White, and Diaz (1987), used Neely's manipulation (described above), wherein nonassociated relations distracted subjects from expecting associated relations. So, for example, following the prime word VEGETABLE, subjects were told to expect an animal as a target. Burke et al. employed this paradigm at two different stimulus-onset asynchronies (SOAs), one thought to capture the automatic range (410 msec) and the other the controlled range (1550 msec). However, expectancy effects were observed at the fastest SOA, meaning that elderly adults were able to direct attentional focus where formerly they had not been thought able to do so. Consequently while Burke et al. show that elderly adults are able to employ attentional direction at rapid SOAs, they do not give a clear picture about whether there is a temporal difference in automatic lexical access between young and old populations, the question of interest here.

Our focus on the issue of "cognitive slowing" in the aged takes the form of an analysis of the elderly subject's ability to perform language processing within both the automatic and the controlled attentional range. While each mode of processing characterizes a distinct temporal range, at some point these ranges must overlap. Here we raise the issue of whether the point at which automatic and controlled processing intersect is an age invariant feature, or whether there is an extension or protraction of the range of one of the processing modes in aging adults. In particular, we focus on rise and fall times for automatic processes.

In the experiments reported below, the time between the presentation of words in a list was varied and we were thus able to examine whether elderly subjects demonstrated a rise and fall of automatic priming that is similar to or slower than that of younger subjects. Based on earlier work (Prather & Swinney, 1988), we expected an onset of priming for college-age subjects between 300 and 500 msec. Because we did not know when to expect the onset for the elderly subjects we ran subjects in two ranges, a fast range to accommodate the college-age subjects and a slower range to accommodate.the possibility of a slower onset of priming for the elderly subjects, (Experiment A and Experiment B, respectively). We chose to have one ISI overlap so that we could compare the data from the two experiments (300-500-800 msec ISIS in Experiment A and 800-1100-1500 msec ISIs in Experiment B). We ran Experiment A and Experiment B with identical materials, with the only variation between the two experiments being the range of ISIs examined. Consequently, the experiments are introduced and discussed together, while the subject group and data analysis are presented separately.

MATERIALS AND METHODS

Subjects. Experiments A and B each included six elderly adults, with a mean age for Experiment A of 65.1 years (range from 59 to 69 years) and a mean age for Experiment B of 63.6 years (range from 57 to 69 years). One subject had 11 years of education; nine were high school graduates; one was a college graduate. Both Experiments A and B also included six college-age subjects (all college students or recent college graduates), with a mean age for Experiment A of 21.8 years (range from 20 to 24 years) and a mean age for Experiment B of 22.8 years (range from 22 to 24 years). The elderly adult subjects were paid volunteers from the Boston VA Medical Center community. The college-age subjects were paid volunteers from the Boston University Community. All subjects had normal or corrected vision, had no history of neurological disease or head trauma, and were native speakers of English.

Materials. The experimental materials included 96 related word pairs (e.g., "cabbage-lettuce") and, in addition, 96 matched control pairs (e.g., "capsule-lettuce") wherein the prime word was replaced by a word of the same length and frequency but unrelated in meaning to the target word (with frequencies taken from Kucera & Francis, 1976). Associates were selected on the basis of published norms (Jenkins, 1970; Keppel & Strand, 1970; Postman, 1970) plus data obtained by polling both college-aged and elderly adults for their first associates to experimental words. The final set of associates represents the experimenters' selections, based on those norms and polled associations, of a set of strongly associated lexical items (see Appendix).

Two lists, I and II, were constructed using these 96 related and 96 control pairs. Each list contained 48 related and 48 control pairs; if the related pair for a particular target word was in the first list, then its matched control was in the second list, and vice versa, so that a target word occurred only once in List I and in List II, either with a related or a control word preceding it. In addition, each list included 108 nonexperimental filler words and 300 pronounceable nonwords, for a total of 300 words and 300 nonwords per list. Finally the word "WORD" (Experiment 1) or the word "BLANK" (Experiment 2) appeared randomly one time in every 15 items across both lists. The rationale for including these repeated words in the list priming paradigm (LPP) was that as ISIs increase between words, it becomes more feasible to look for relations among words. The most likely relations to be noticed and therefore to invite attentional strategies or expectations are the relations between repeated words and the words following them. In that sense, the repeated word was intended to distract the subject from applying strategic processes in "watching for" associative relations.

The two lists were then divided into three segments (segment A, B, and C); each segment included 16 related target and 16 control target pairs, as well as filler words and nonwords, totalling 200 stimuli per segment. Each subject saw either the three segments from List I or the three segments from List II, and saw each of those segments at a different ISI (300, 500, and 800 in Experiment 1; 800, 1100, and 1500 in Experiment 2). The segments were always presented in the same order, but the order in *which* ISIs were presented was counterbalanced across subjects. Consequently, across six subjects, each segment, A, B, and C from Lists I and II, was seen once at each ISI.

Design. The design was a mixed factorial design, with the factor "Age" as a between-subjects factor, and the factors "Relatedness' and "ISI" as within-subjects factors.

Apparatus and procedure. The 600 test items were presented visually on a Panasonic video monitor connected to a Compaq Computer with an internal clock (Metrabyte CTM05) accurate to milliseconds. Subjects were seated in front of a button box and required to use their nondominant hand. Subjects were instructed to respond to the single word presented in the center of the screen by pressing the right button labeled "yes" if the viewed word was an English word, or by pressing the left button labeled "no" if the viewed word was a meaningless nonword. The letter string remained on the screen until the subject responded. ISI began immediately with the subject's response so that an ISI of 300 msec represented the elapsed time between the *response* to one word and the *presentation* of the next word. Throughout the experiment, subjects rested one finger on each of the two buttons. Initially, subjects viewed a 20-word-long practice list with 10 real words and 10 nonwords arranged randomly. Following the practice list, the test items were presented with a short break every 25-30 words.

RESULTS

The question under investigation was whether or not there was slowing of automatic lexical access as a function of age. This was examined by varying the amount of time between prime and target words embedded in long lists of words and by determining the shortest and longest ISIs at which facilitation effects were obtained. Facilitation effects are represented as the difference between lexical decision time to target words preceded by a related prime (e.g., "cabbage-lettuce") and that to target words preceded by a control prime (e.g., "capsule-lettuce").

The differences among reaction times to related and control pairs as a function of ISI were examined statistically by analysis of variance across the factors of Age (2) x ISI (3) x Relatedness (2), with Age as the between-subjects variable and ISI and Relatedness as within-subject variables. In addition, the data were examined by planned comparisons (one-

TABLE 1
MEAN REACTION TIMES TO WORDS PRECEDED BY RELATED VS. CONTROL PRIMES AS A FUNCTION OF ISI (300, 500, OR 800 msec)

Group	ISI (msec)	Related prime (msec)	Control prime (msec)	Priming effect (Related-Control) (msec)
Young subjects	300	516	511	-4 (p = . 404)
	500	514	532	+18 (p < .003)
	800	515	526	+9 (p = . 542)
Old subjects	300	581	580	-1 (p = . 407)
	500	573	608	+35 (p = . 042)
	800	588	613	+25 (p = . 086)

way ANOVAs; see Keppel, 1982) examining the difference between reactions times to each related vs. control pair at each ISI.

Before conducting these statistical analyses, the reaction time data were first screened for errors (total of 7 and 6% for elderly and college-aged subjects, respectively, Experiment 1). The data were also screened for outliers (reaction times more than 2 standard deviations above or below the subject's mean reaction time) (total of 4 and 3% screened, respectively, for elderly and college-aged subjects, Experiment 1). Finally, the screened reaction times were log-transformed. Each subject's mean for each condition of ISI x Relatedness was calculated based on their non-error log-transformed reaction times; those means were then subjected to statistical analyses. (See Table 1 and Table 2 for summary of reaction time data, Experiments 1 and 2, respectively) Referring to Tables 1 and 2, it is apparent that there is no difference between the *pattern* of the data collected from the elderly adult subjects and college-age subjects in the present study. For both elderly adult and college-aged subjects the

TABLE 2
MEAN REACTION TIMES TO WORDS PRECEDED BY RELATED VS. CONTROL PRIMES AS A FUNCTION OF ISI (800, 1100, OR 1500 msec)

Group	ISI (msec)	Related prime (msec)	Control prime (msec)	Priming effect (Related-Control) (msec)
Young subjects	800	450	467	+17 (p = . 270)
	1100	454	463	+9 (p = . 087)
	1500	445	459	+14 (p = . 210)
Old subjects	800	556	579	+21 (p = . 082)
	1100	569	582	+13 (p = . 255)
	1500	587	581	-6 (p = . 607)

difference between related pair and control pair target reaction times increased as ISI is lengthened from 300 to 500 msec and then diminished after the 800-msec ISI.

For Experiment 1 (ISIs of 300, 500, and 800 msec), an analysis of variance across the factors of Age (2) x ISI (3) x Relatedness (2) showed no main effects or interactions. (The main effect for Age approached but did not reach significance, ($F(1, 10) = 4.4015$, $p = .062$.)) Based on planned comparisons, the only statistically reliable difference between related and control pairs was observed at 500 msec for both the elderly and the college-aged subjects, ($F(1, 5) = 7.317$, $p = .042$ and $F(1, 5) = 29.851$, $p < .003$, respectively). There were no other significant differences for either subject group.

For Experiment 2, again, errors and outliers were removed (total of 3% error for both elderly and college-aged subjects; total of 3.5 and 4% screened outliers, respectively, for elderly and college-aged subjects), the remaining reaction times were lob transformed, and those screened data were subjected to analysis of variance. The results of the analysis of variance showed a main effect for Age ($F(l, 10) = 14.461$, $p < .01$) and for Relatedness ($F(1, 10) = 9.41$, $p < .02$). Reaction times for college-aged subjects were faster overall than those for the elderly subjects (mean = 575 msec for elderly, 457 msec for college-aged subjects). Also, at most ISIs, reaction times to words preceded by a Related prime were faster than reaction times to words preceded by a Control prime (mean = 510 msec for Related, 522 msec for Control overall). Based on planned comparisons, however, those differences were not significant at any ISI, and at best approached significance at the 800-msec ISI, for the elderly subjects and at 1100 msec for the college-aged subjects (see Table 2). Also, neither Age nor Relatedness interacted with any other main effect. There was no main effect.for ISI, nor did ISI interact with any other variable. In sum, results of Experiment 2 support an inference that priming does not obtain reliably at longer ISIs for either college-aged or elderly subjects. While there is always a slight positive priming effect at these longer ISIs (reflected in the positive effect of Relatedness overall), that effect is arguably due to idiosyncratic individual responses to related pairs and not to an automatic priming response that is consistent across subjects. It would not be surprising to find that most subjects are able to anticipate *some* relations among *some* experimental word pairs as ISIs increase (lending a slight positive effect overall for related pairs), but it is apparent that that effect is not consistent and therefore not reflected in the individual pairwise comparisons in the way that it is at the shorter, 500-msec ISI.

The results of Experiments 1 and 2 taken together suggest that, whatever may be slowing about lexical processing with age, slowing does not occur in rapid, automatic access to lexical information. While mean reaction times were slightly slower for our elderly relative to those for our college-aged subject group, the rate at which lexical items were accessed showed no differences. Both college-aged and elderly subjects showed their earliest (and only significant) priming effects at an ISI of 500 msec.

DISCUSSION

In order to determine the time course of lexical access in the aging adult, facilitation effects to semantically related words were measured at six different ISIs. The results show that elderly and college-aged subjects present a similar pattern of priming that begins at short ISIs (500 msec) and diminishes between 800 and 1100 msec. These current results suggest, then, that wherever the locus of age-related slowing may be, it is not in the early stage, language-specific processing devices that mediate rapid lexical access. Rather, our data suggest that older adults show the same temporal onset of lexical access as younger populations.

It should be noted that Howard et al., (1986) make a claim contradictory to ours, finding that aging adults slowed in relation to younger adults at very rapid (150 msec) SOAs. But as pointed out in the introduction, the distinction between automatic and controlled processes is hard to make when using, as Howard does, a pairs paradigm coupled with instructions directing subjects to expect relations between the presented words. In addition, the younger subjects demonstrated longer response latencies to the pairs presented in the 150-SOA condition in comparison to the pairs presented in the 450- and 1000-msec SOA conditions. Since shorter SOAs characteristically yield *faster* response latencies, this finding suggests that the 2-sec between-pair interval allowed subjects to perform some reprocessing and thus allowed them to reflect upon the relation between the words before making a response. This allowance for reprocessing may have led to a situation wherein the younger subjects were actually utilizing attentional, controlled processing in the 150-msec SOA condition, contrary to Howard et al.'s (1986) claims to automaticity.

Where the present study examined the time course of lexical access, two other studies have directed investigations to other aspects of lexical organization and access, and similarly have found no difference between young and elderly adults. Specifically, both Tainturier, Tremblay, and Lecours (1989) and Bowles and Poon (1981) have demonstrated a similar effect of word frequency on strength of priming effects for young and elderly adults, this, too, being a reflection of automatic and unconscious processing.

We also note another piece of evidence: young adults consistently show full access to all meanings of lexical items automatically, regardless of contextual factors (e.g., Swinney, 1979; Simpson, 1981), evidence that favors an argument that lexical access routines are exhaustive and en capsulated. Recently, pilot work in our laboratory suggests strongly that the elderly also show exhaustive access for polysemous words in the same way as college-aged adults.

Granting that lexical access does not slow, with age, we propose the following more general point: that language specific processes that are routinized do not slow with aging. Rather, slowing is vested in central processes that are not domain specific and that place demands on attention and other resource-limited processes (e.g., Howard et al.). Intentionally directed rather than automatically accessed information is, on this view, vulnerable to aging.

APPENDIX: EXPERIMENTAL STIMULI

Control word	Prime word	Target
SAILOR	SPIDER	BUG
VINE	SOCK	SHOE
TRACE	PLATE	DISH
TOY	PIG	HOG
MESSENGER	VEGETABLE	FRUIT
FLASH	SHEEP	LAMB
SWEATER	SHERIFF	DEPUTY
CLUE	LUNG	HEART
DEBATE	BALLET	DANCE
DUKE	FUEL	GAS
CHICKEN	SOLDIER	ARMY
TRAIN	WATCH	CLOCK
ACID	PONY	HORSE
PROTEST	COTTAGE	CABIN
INSTRUCTOR	UMBRELLA	RAIN
LIMB	TOAD	FROG
SHIFT	SMOKE	CHIMNEY
PATH	COAT	JACKET
VOICE	FIELD	PASTURE
ROLE	CARS	TRUCKS
SAMPLE	RUBBER	PLASTIC
THIGHS	THREAD	NEEDLE
ADVISE	AUTHOR	WRITER
PUZZLE	SALOON	BAR
NIGHT	HOUSE	HOME
PICKET	PILLOW	BED
MOLD	MOON	STAR
STAGE	FLOOR	CEILING
PAN	CAB	TAXI
MOLECULE	BUTTERFLY	MOTH
GRIEF	MOUSE	RAT
ROBE	LAMP	LIGHT
ROLLER	ROBBER	THIEF
PLUG	BEND	CURVE
SLEEVE	SKETCH	DRAW
AIRPLANE	DENTIST	TEETH
PRIDE	PORCH	PATIO
NEWS	PAIN	ACHE

APPENDIX-Continued

Control word	Prime word	Target
MASTER	CIRCLE	SQUARE
STREETCAR	LIGHTENING	THUNDER
FRAME	DREAM	SLEEP
SIGN	FILM	CAMERA
ALARM	APPLE	ORANGE
MERIT	SUGAR	FLOUR
ADDRESS	TEACHER	SCHOOL
CAFE	LION	TIGER
TENNIS	NICKLE	QUARTER
PRAISE	BLOUSE	SHIRT
CLASS	CHILD	BABY
ADVICE	ENGINE	MOTOR
REPORT	MARKET	STORE
CHORE	SHOUT	YELL
SADDLE	ILLNESS	DISEASE
DOZEN	SMILE	GRIN
GRAM	GOWN	DRESS
CAMP	DUST	DIRT
REGARD	DOCTOR	NURSE
DAWN	KING	QUEEN
LESSON	COTTON	WOOL
EVENT	RIVER	STREAM
CRIMINAL	ENVELOPE	STAMP
FRIEND	EARTH	SOIL
SELF	HILL	MOUNTAIN
COPPER	HAMMER	NAIL
THUMB	BROOM	MOP
STRAW	STOVE	OVEN
RANGE	STREET	ROAD
TITLE	RIFLE	PISTOL
SOAP	JOKE	RIDDLE
HEALTH	BRIDGE	TUNNEL
CAPSULE	CABBAGE	LETTUCE
REPLY	OCEAN	WATER
RUSH	JAIL	PRISON
CURSE	SPICE	CINNAMON
PEPPER	RABBIT	CARROT
BODY	CITY	TOWN
WILDERNESS	CHOCOLATE	VANILLA
LICENSE	STOMACH	FOOD
BIRTH	TABLE	CHAIR
SALT	SKIN	FLESH
SNOW	ROCK	STONE
CRISIS	BOTTLE	JAR
FOOL	GATE	FENCE
TEMPER	MITTEN	GLOVE
NOVELIST	CUCUMBER	PICKLE
PERIL	EAGLE	BIRD

APPENDIX-Continued

Control word	Prime word	Target
GRASS	WHEEL	TIRE
PIT	PIE	CAKE
DESPAIR	SERVANT	MAID
GLOW	FORK	SPOON
GOSSIP	CARPET	RUG
ATTIC	ELBOW	KNEE
CATTLE	DINNER	LUNCH
BRASS	PRIZE	AWARD
CANE	PRAY	WORSHIP
STATIC	CASTLE	PALACE
SCALE	CROWD	PEOPLE
EXAMPLE	GENERAL	COLONEL
STACK	CLOWN	CIRCUS
KIND	DOOR	WINDOW
CLEANER	WHISKER	BEARD
HEALER	COOKIE	CRACKER
ANVIL	CAMEL	HUMP

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