

In the present study, we are attempting to determine whether elderly adults who exhibit working memory overload with a single level of embedding could also use semantic constraints, as young adults do, to overcome this processing difficulty. Given the availability of semantic information, can elderly adults utilize this information to bypass syntactic processing of complex sentences or compensate for processing deficits?

Two experiments were performed since elderly adults' performance may be influenced by task demands more than that of young adults. In the first, the participants were required to demonstrate that they had understood of the semantic relations in sentences with embedded relative clauses. In the second, the participants were asked to discriminate between old and new sentences which contained relative clauses.

Experiment 1

Participants. Twenty-four undergraduates at the University of Kansas and 59 elderly persons were tested. The undergraduates were enrolled in an introductory psychology class and received course credit for their participation. The elderly participants were recruited from the community through advertisements and personal contacts. They received \$20 for their participation. All were healthy individuals living at home or with relatives. Thirty-six of the elderly participants were seen in their homes and twenty-three were seen in the university laboratory. All participants were native English speakers. The elderly adults had previously participated in a series of studies as reported in Kemper Rash, Kynette & Norman (1990), Kemper, Kynette & Norman (in press), and Kemper, Kynette, Rash, Sprott, & O'Brien (1989).

The undergraduates were between 19 and 29 years old with a mean age of 19.8 years and a standard deviation of 2.45; there were 13 males and 11 females. Two subgroups of elderly participants were established: a young-old group between 60 and 74 years and an old-old group between 75 and 90 years. In the young-old group, there were 39 participants with a mean of 69.2 years and a standard deviation of 3.08; there were 13 males and 26 females. There were 20 participants in the old-old group with 4 males and 16 females; the mean age was 80.6 years with a standard deviation of 3.95.

Materials. The critical syntactic manipulation involved branching direction. The subject- versus object-relative clauses either modified the subject of the main clause, e.g., The tailor whom the woman called had seen the emblem" producing a left-branching sentence or they modified the direct object of the clause, e.g., The manager disliked the chef who baked the cake, producing a right-branching sentence.

In addition to branching direction, the materials contrasted semantically reversible and semantically constrained sentences. For half of the sentences, the subject and direct object in each clause could be reversed without making the clause illogical, e.g., The boy chased the dog and The dog chased the boy. The other half were constrained such that the subject and direct object in each clause could not be reversed without making the sentence illogical, e.g., The squirrel climbed the tree and *the tree climbed the squirrel.

The sentences were constructed from the reversible and constrained clauses to control another syntactic factor which contributes to syntactic processing difficulty (Fodor, Bever, and Garrett, 1974; Waters, Caplan, and Hildebrandt, 1987; Feier and Gerstman, 1980): locus of embedding, subject- versus object-embedding, and voicing. Example sentences are listed in Table 1.

Procedure. Participants were tested individually or in pairs in one-hour sessions. The participants were given a response booklet along with a set of written instructions. The experimenter read the instructions along with the participant. Participants were informed that they were to match each noun from the sentence with the appropriate verb. They were informed that the sentences involved a subject or actor who did something, a verb, or action to an object. To indicate that they understood each sentence, participants were instructed to draw an arrow from the subject that did the action to the object and write the verb or action on the arrow. This procedure was adapted from Cook (1975).

The sentences were read to the participants one at a time by the experimenter at a normal pace without contrastive stress or emphasis on any words. Participants were not permitted to start writing until the experimenter had finished reading each sentence. After each sentence was read, the participant filled in

 Table 1. Examples of Sentences Used in the Sentence Comprehension Task

Reversible Object-relative

Left-branching: The woman whom the man interviewed dropped the bag.

Right-branching: The manager had liked the clerk whom the owner fired.

Reversible Subject-relative

Left-branching: The actor who was portraying the doctor hugged the nurse.

Right-branching: The gentleman followed the woman who bought the furniture.

Constrained Object-relative

Left-branching: The singer whom the fan kissed sang the song.

Right-branching: The helicopter transported the boxes which the medic supplied.

Constrained Subject-relative

Left-branching: The engine which leaked oil gave off smokey fumes.

Right-branching: Lightening struck the witch who cast the spell.

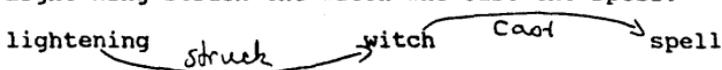
the response booklet. None of the sentences were repeated. The participants were instructed to leave the item blank if they could not remember the relationships or did not know the answer.

Each clause in each sentence was scored as correct if the participant appropriately identified who did what to whom by drawing an arrow in the correct direction and labelling the arrow with the appropriate verb. See Table 2 for examples. Clauses were scored incorrect if there was no response, or if an arrow was drawn to the incorrect noun or verb. If the participant did not clearly indicate the relationship between the nouns, the response was scored as ambiguous. Arrows drawn opposite to the correct direction were scored as reversals. Overall, only 3.8% ambiguous responses were scored and 3.6% reversals; therefore, these errors were not analyzed further. The participant's total score on this task was determined by assigning one point for each correct clause with a maximum of 48 possible points.

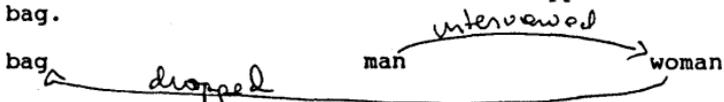
Results. The design was a 3 age group x 2 levels of constraint (constrained or reversible) x 2 levels of locus of relative clause (object- or subject-relative) x 2 levels of direction (left- or right-branching) ANOVA. The primary result was a significant, three-way interaction between Constraint, Branching Direction, and Age. See Figure 1.

Table 2. Response Form

1. Lightening struck the witch who cast the spell.



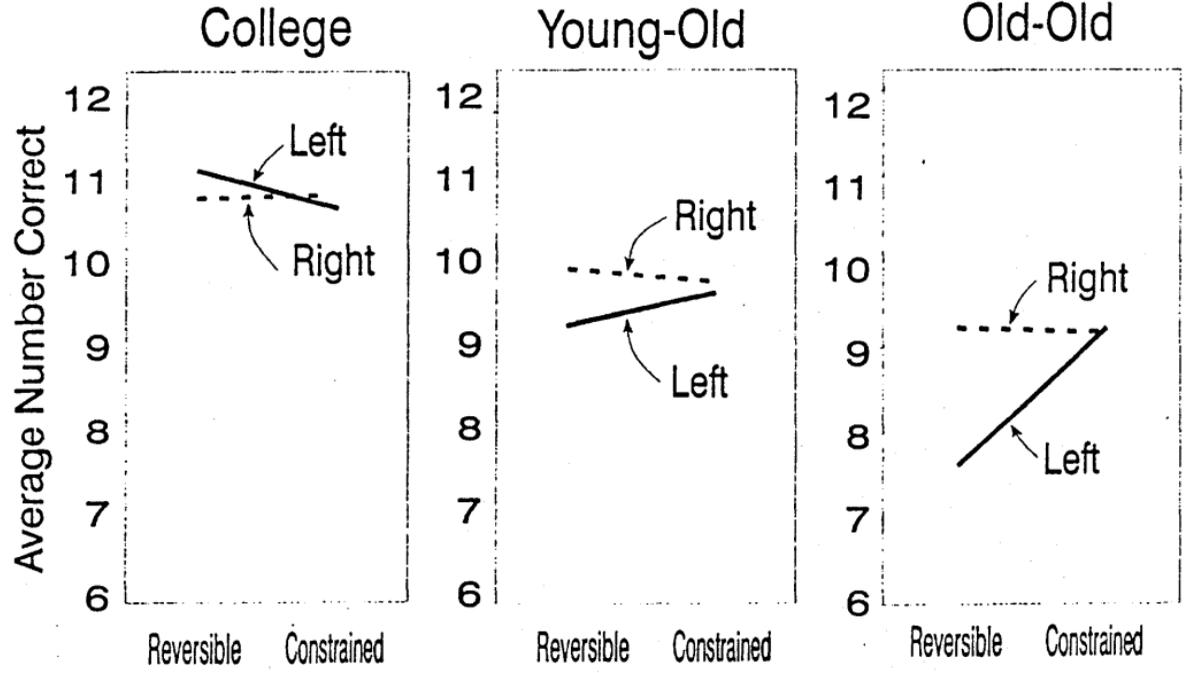
2. The woman whom the man interviewed dropped the bag.



The college group performed equally well regardless of the syntactic form. The young-old group's performance was affected by the combination of branching direction and constraint. They performed more poorly on reversible, left-branching sentences than on the other types of sentences. Both constraint and branching direction affected the performance of the old-old group; overall, they performed more poorly on left- than right-branching sentences and more poorly on reversible than constrained sentences. Reversible, left-branching sentences were particularly difficult for the old-old group.

Discussion. The results lend further support to the hypothesis that elderly adults suffer from a deficit in working memory which appears to be progressive with increased age and which limits their listening comprehension. Performance on the comprehension task, especially for the reversible, left-branching sentences, declined significantly for the young-old group and precipitously for the old-old group relative to that of the college group. Since task required that the adults' not only retain multiple semantic relations in working memory but also determine the syntactic roles of each element in each clause, it may have overburdened the working memory central

Figure 1
Interaction of Age, Constraint, & Branching Direction



executor as suggested by Baddeley's (1986) view of age-related declines.

One question was whether elderly adults could use semantic information in sentences to compensate for syntactic processing problems. The results of this study indicate that elderly adults can use semantic constraints to facilitate comprehension in order to reduce working memory load during the processing of left-branching clauses.

This finding complements earlier research done by Wingfield and Stine (1989) which shows that elderly adults may become more reliant upon alternative features of language, such as prosody, when working memory becomes overloaded. However, this compensatory strategy was only partially effective since there was nonetheless an age-related decline in overall comprehension.

Experiment 2

Participants. Twenty-four undergraduates at the University of Kansas and 54 elderly persons were tested. The undergraduates were enrolled in an introductory psychology class and received course credit for their participation. The elderly participants were recruited from the community through advertisements and personal contacts. They received \$20 for their participation. All were healthy individuals living at home or with relatives. All participants were native English speakers. The elderly adults had previously participated in Experiment I.

The undergraduates were between 18 and 23 years old with a mean age of 19.1 years and a standard deviation of 1.06; there were 14 males and 8 females. Two subgroups of elderly participants were established: A young-old group who were between 62 and 74 years and an old-old group 75 and above. In the young-old group, there were 38 participants with a mean of 69.9 years and a standard deviation of 3.13; there were 11 males and 27 females. In the old-old group, there were 16 participants with 3 males and 13 females; the mean age was 80.9 years with a standard deviation of 4.03.

Materials. The recognition task contained three types of sentences: OLDS, FOILS, and NEWS. (1) The OLDS were those sentences presented during the learning phase of the experiment. (2) FOILS were constructed by altering either the syntactic or semantic form of the

sentence. Reversible sentences had their objects and subjects reversed. Constrained sentences were converted from left-branching to right-branching or vice versa. The FOILs controlled for the use of two lexically-based strategies by testing whether the participants could detect semantic reversals or syntactic alteration. In other words, if participants remembered just lexical items from the OLDs, then they would incorrectly "recognize" FOILs. See Table 3 below for examples. (3) NEWs were constructed by creating completely new sentences with lexical items that did not overlap with the OLDs. The NEWs controlled for the use of a simple guessing strategy as well as any syntactic biases.

 Table 3. Examples of FOIL construction.

Semantic Reversal

The schoolgirl whom the lawyer likes kissed the
 invalid.

The lawyer whom the schoolgirl likes kissed the
 invalid.

Syntactic Reversal

The waiter who argued with the manager dated the
 bartender.

The bartender dated the waiter who argued with the
 manager.

The critical syntactic manipulations involved branching direction and locus of embedding as in Experiment 1. The subject- versus object-relative clauses either modified the subject of the main clause, e.g., The tailor whom the woman called had seen the emblem producing a left-branching sentence or they modified the direct object of the clause, e.g., The manager disliked the chef who baked the cake, producing a right-branching sentence. In addition to branching direction and locus, the materials contrasted semantically reversible and semantically constrained sentences as in Experiment 1.

To ensure that the sentences were constrained and reversible as intended, a validation study was performed as in Experiment I. The final experimental sentences were selected so that both clauses of the reversible sentences were judged to be reversible according to the validation study. The constrained sentences were selected such that at least 80% of the

students preferred the correct version while no more than 20% of the students preferred the reversed version. Thirty-two sentences met these criteria.

The experimental materials consisted of two lists of 32 sentences selected from the validation study. The lists were counterbalanced for branching direction. Test sheets were created containing a question probing either the main or embedded clause in the sentence. There were two forms of each test alternating questions about main and embedded clauses. These were created in order to ensure that the participants paid attention to each sentence as it was presented. Response booklets were created to correspond to each of the test forms.

Procedure. Participants were tested individually in one-hour sessions. The participants were given a set of written instructions along with the first test sheet containing the questions corresponding to each sentence. The experimenter read the instructions along with the participant. Participants were informed that they were to answer each question immediately after hearing the sentence read by the experimenter.

The sentences were read to the participants one at a time by the experimenter at a normal pace without contrastive stress or emphasis on any words. Participants were not permitted to start writing until the experimenter had finished reading each sentence. After each sentence was read, the participant filled in the test sheet. None of the sentences were repeated. The participants were instructed to leave the item blank if they could not remember the relationships or did not know the answer. Accuracy on this acquisition test was nearly 100% for all participants.

After hearing the entire list of sentences and answering the corresponding questions, the participant was given a response booklet containing 80 items. They were given a set of written instructions which the experimenter read with them. They were informed that they were to read each sentence and decide if it was one of the ones they heard. If it was exactly the same as one of the original sentences, they were to respond OLD, otherwise they were instructed to respond NEW. They were also asked to rate the confidence with which they made their judgement -- "very sure", "somewhat sure", "only guessing".

Each sentence was scored as correct if the participant appropriately identified OLDS as old and

FOILs and NEWS as new. The sentences were scored incorrect if there was no response or if the participant inappropriately identified OLDs as new, or incorrectly "recognized" FOILs or NEWS as old.

Results. Performance on the NEWS was nearly at ceiling for all of the groups across all clause types. Since a preliminary analysis indicated that the three age groups did not differ in their recognition of NEW items, this item type was omitted in later analyses. Consequently, the overall design was a 3 age group x 2 item types (OLD, FOIL) x 2 levels of constraint (constrained or reversible) x 2 levels of locus of relative clause (object- or subject-relative) x 2 levels of direction (left- or right-branching) ANOVA.

Item X Constraint interaction: For the FOILs, reversible sentences ($M = 64\%$) were easier to recognize than constrained sentences ($M = 50\%$). In contrast, for the OLDs, reversible sentences ($M = 57\%$) were slightly more difficult to recognize than constrained sentences ($M = 61\%$) but not significantly so. Thus, for OLDs, the participants retained some memory for the verbatim form of the sentence. In contrast, for the FOILs, the participants may have relied on a semantically-based guessing strategy. This strategy appeared to help them reject semantically reversed FOILS but did not aid their recognition of OLDs.

Item X Locus interaction: For OLDs, performance on the object-relative sentences ($M = 59\%$) equaled that of subject-relative sentences ($M = 58\%$), indicating some retention of verbatim form of the OLD sentences. For the FOILS, object-relative sentences were slightly more easily recognized ($M = 60\%$) than their subject-relative counterparts ($M = 54\%$). It appears, again, that the participants relied on a guessing strategy, perhaps one favoring sentence subjects and, hence, object-relative FOILS.

Age X Item interaction: The college-aged group equally well on OLDs and FOILS ($M = 63\%$ and $M = 63\%$, respectively). In contrast, the young-old group correctly recognized more OLDs ($M = 60\%$) than FOILS ($M = 51\%$) whereas the old-old group correctly recognized fewer OLDs ($M = 49\%$) than FOILS ($M = 61\%$). Thus, the college group appears to have retained the verbatim form of the original sentences whereas the young-old group appears to have been unsuccessful in their attempt to do so while the old-old group appears to have adopted a semantically-based guessing strategy

that enabled them to correctly recognize semantic reversals of the FOILs.

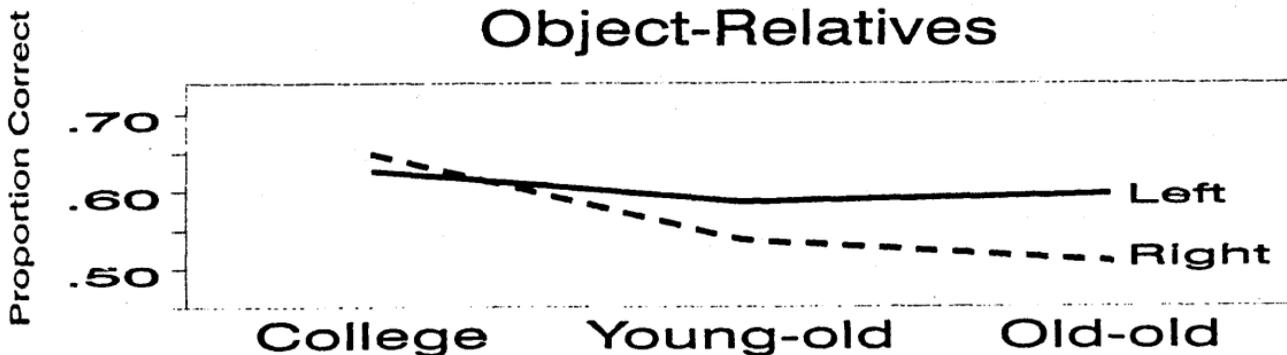
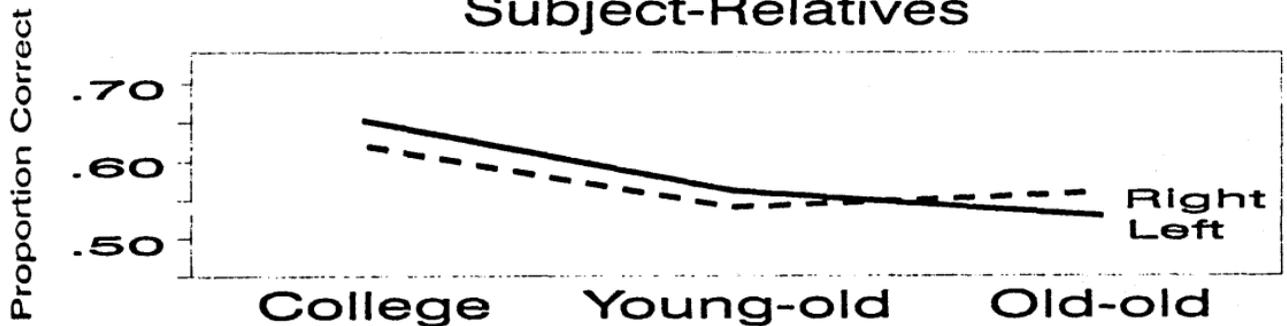
Age x Locus x Branching Direction interaction: See Figure 2. With this task, there was an age-related decline in performance but it was highly specific with regard to sentence type. All three age groups performed approximately equally well for subject-relatives regardless of branching direction.

In contrast, for object-relative sentences, the three age groups were equivalent for left-branching sentences (college: M = 63%; young-old: M = 59%; old-old: M = 60%), but not for right-branching sentences. College students correctly recognized more right-branching, object-relatives (M = 68%) than did the young-old (M = 56%) and old-old (M = 53%) participants. This interaction suggests that the college students' were able to out-perform the two elderly groups only on one type of sentence: right-branching, object-relatives.

Discussion. The results of Experiment 2 confirmed the hypothesis that elderly adults' syntactic processing is affected by task demands. Unlike Experiment 1, where there was a consistent age-related decrement in performance for the young-old and old-old groups, elderly adults were able to perform as accurately as young adults for three of the four types of sentences. For these sentences, the elderly adults, even the old-old group, were able to correctly recognize as many OLDs and reject as many FOILs as the college students; right-branching, object-relatives were the exception.

This finding suggests that the elderly adults were able to develop compensatory strategies to overcome syntactic processing problems. Whereas the students seemed to have relied on verbatim memory for the sentences, favoring OLD sentences, the old-old group seem to have adopted a guessing strategy based on meaning. This guessing strategy was sufficiently accurate to enable them to detect semantic reversals (eg. FOILs derived from reversible sentences) but it did not help them with the syntactic FOILs derived from constrained sentences. They also seem to have adopted a subject-based strategy that helped them to correctly recognize both left- and right-branching subject-relative clause sentences. Only in the case of object-relative clause sentences were the elderly adults unable to devise successful compensatory strategies.

Figure 2
Age x Locus x Branching Direction Interaction
Subject-Relatives



General Discussion

The results of Experiments I and II provide further evidence for the hypothesis that elderly adults suffer from deficits in working memory. Certain syntactic factors, such as left-embedding, increase the processing load on working memory and make sentences more difficult to comprehend and hence remember. Elderly adults perform poorly on such sentences, reflecting an age-related loss of working memory capacity. Elderly adults can, nonetheless, exploit semantic constraints to reduce the syntactic processing load and elderly adults can develop alternative strategies to aid their performance. The use of such strategies indicates that adults are not, as suggested by Emery (1985), simply regressing back to childish forms of speech. Rather, in the face of working memory deficits, the elderly adults rely more heavily on alternative features of language.

This finding suggests why elderly adults may not experience syntactic processing problems with ordinary, everyday listening tasks. Well-formed discourse generally is thematically organized and topically constrained. Hence, ordinary discourse and spoken language is repetitive and redundant. Intuitively, it would appear that elderly adults could take advantage of these semantic redundancies to overcome any syntactic processing problems. To the extent that technical prose, such as television news programs, are not so constrained, elderly adults' comprehension may suffer from syntactic processing limitations.

Elderly adults' performance is also influenced by task demands. The demanding, verbatim recall task of Experiment I produced consistent age-group differences which were not obtained in the easier, recognition memory task in Experiment II. Thus, elderly adults' may be able to avoid syntactic processing problems and other working memory impairments whenever task demands are minimal.

Note

¹This research was supported by grant RO1AG06319 from the National Institute on Aging to S. Kemper.

References

- Baddeley, A. D. 1986. Working Memory. Oxford: Clarendon Press.
- Botwinick, J. 1984. Aging and Behavior: A Comprehensive Integration of Research Findings. New York: Springer.
- Cook, V. J. 1975. Strategies in the comprehension of relative clauses. Lang.Sp. 18.204-212.
- Emery, O. 1985. Language and aging. Exper.Ag.Resc. 11. 3-60.
- Feier, C. D. & L. J. Gerstman. 1980. Sentence comprehension abilities throughout the adult life span. J.Ger. 35.727-728.
- Fodor, J. A., T. G. Bever, M. Garrett. 1974. The Psychology of Language. New York: McGraw-Hill.
- Kemper, S. 1988. Geriatric psycholinguistics: Syntactic limitations of oral and written language. Language, Memory, and Aging. Cambridge, ed. by L. Light and D. Burke. Cambridge University Press.
- Kemper, S. in press. Language and Aging. Handbook of Cognitive Aging, ed. by F. Craik and T. Salthouse.
- Kemper, S. & Rash, S. J. 1988. Speech and writing across the life-span. Practical Aspects of Memory: Current Research and Issues, ed. by M. M. Gruneberg, P. E. Morris, & R. N. Sykes. London: Wiley.
- Kemper, S., S. Rash, D. Kynette, & S. Norman. 1990. Telling stories: The structure of adults' narratives. Eur.J.Cog.Psych. 2.205-253.
- Kemper, S., D. Kynette, S. Rash, R. A. Sprott, & K. O'Brien. 1989. Life-span changes to adults' language: Effects of memory and genre. App.Psychol. 10.49-66.
- Kynette, D. & S. Kemper. 1986. Aging and the loss of grammatical forms: A cross-sectional study of language performance. Lang.Comm. 6, 43-49.
- Waters, G., Caplan, D., & Hildebrandt, N. 1987. Working memory and written sentence comprehension. Attention & Performance XII: The Psychology of Reading, ed. by Max Coltheart. Lawrence Erlbaum.