A comparison of structural equation models of memory performance across noise conditions and age groups

Staffan Hygge[1]*, Ingela Enmarker[1,2,3], Eva Boman[2]

1 Centre for Built Environment, University of Gävle, SE-801 76 Gävle, Sweden

2 Department of Education and Psychology, University of Gävle, SE-801 76 Gävle, Sweden

3 Department of Health, Campus Namsos, Nord-Trøndelag University College, Serviceboks 2501, NO-7729 Steinkjer, Norway

* corresponding author: e-mail: Staffan.Hygge@hig.se

INTRODUCTION

In a recent study (Enmarker et al. 2006) structural equation models (SEM) of memory performance across noise conditions and age groups were compared and tested. The latent variable structures were basically invariant across the three noise conditions (quiet, road traffic, and irrelevant speech). For the four age groups (13-14, 18–20, 35–45, and 55–65 years) the latent variable structures wtere invariant across the three older groups, but the youngest group stood out from the others. The pupils in the youngest group who performed best on the memory tasks showed a SEM memory structure that was similar to the group aged 18-20 years, but those who performed worse did not. This may signify something of a developmental shift in cognitive development.

In the present study more detailed contrasting models of the memory performance of the three noise conditions and four age groups are formulated and tested. In particular, an attempt is made to identify memory structures for the group aged 13-14 years that can account for differences in memory structure in that group and give a hint about the nature of their memory development and susceptibility to noise.

METHODS

Participants and Basic Design

Participants (total *N* = 288) were randomly assigned to each of three independent groups: (a) road traffic noise, (b), meaningful irrelevant speech and (c) silence. This was crossed with four age groups, with an equal number of male and female participants in each of the noise conditions in the age groups 13-14 and 18-20 years. (*N*=96 for 13-14 and 18-20 years). For age groups 35-45 and 55-65 years, *N*=48 in each group, but there were slightly more females in these age groups.

Procedure

The experiments were run in a climate chamber and two to four participants stayed in the experimental room at the same time. The only difference between the three noise groups was the different noise conditions during the first part of the experiment. In the second part of the experiment retrieval measures on all the episodic memory tasks were taken in quiet to unconfound noise effects at encoding and retrieval.

Noise

In the noise conditions digital recordings of meaningful irrelevant speech and road traffic noise were played back through loudspeakers in front of the room. The equivalent sound level (L_{eq}) in the noise conditions was set to 66 dBA 2 m in front of the loudspeakers. The sound level in the quiet control group was 38 dBA L_{eq}.

The road traffic noise recording was made up of a background of continuous traffic noise (~62 dBA) with superimposed segments of trucks passing by. The meaningful irrelevant speech recording consisted of background babble (~62 dBA) without any discernible meaning, with superimposed segments of a dialogue between two teenagers. In the segments only one person was talking at a time. This dialogue was distinct and interpretable, but did not convey much of information. The dBA-against-time history of the traffic noise and the speech noise were matched against other. The peaks (fast) in the superimposed segments were at 78 dBA for both noise sources and occurred on the average once per minute and with different duration. The dominant frequency range for the road traffic noise (100-300 Hz) was lower than that for the meaningful irrelevant speech (500-1500 Hz).

Dependent Measures

See Table 1 for a list of the memory items, their abbreviations, and their assignment to latent variables.

Table 1: Memory items in the latent variables and the abbreviations employed in Figure 1

Abbreviation	Item name
	Items in Episodic memory
	Recall
RCLtxt	Recall of text
FRwE	Free recall with enactment
FRwoE	Free recall without enactment
CRCwE	Cued recall categories with enactment
CRCwoE	Cued recall categories without enactment
CRNwE	Cued recall nouns with enactment
CRNwoE	Cued recall nouns without enactment
	Recognition
RCGtxt	Recognition of text
Face rcg	Face recognition
GN IncL	Given name incidental learning
FN IntL	Family name intentional learning
	Items in Semantic memory
	Knowledge
W comp	Word comprehension
	Fluency
WF A	Word fluency letter A
WF M	Word fluency letter M
WF prof	Word fluency professions

Episodic memory. The participants read a text about a fictitious ancient culture for 15 min at the beginning of the experiment (in silence, road traffic noise or irrelevant speech according to experimental group). They were tested in writing in silence for cued recall and recognition of the text at the end of the experiment.

Several other of our memory tests were adapted from the Betula study of health, memory and ageing. This study is a large (N > 3,000) prospective Swedish study on memory, health and ageing (see Nilsson et al. 1997 for a description).

In testing sentences with and without enactment (Nilsson et al. 1997) the participants were presented with two successive lists in imperative form (e.g., knock on the pan, roll the pineapple) with 16 sentences each. For one of the lists the encoding was done with enactment (Engelkamp 1995). In the Betula project, Nilsson et al. (1997) also developed a face and name recognition task for testing intentional and incidental learning and recognition for non-verbal material in episodic memory. This test was computerized and adapted to group presentation in our experiments. A total of 24 faces and names were presented during testing. Twelve were target faces and names of the 16 presented initially, and 12 were distractor faces and names. Target and distractor faces appeared one by one for 15 s on the computer screen in a random order.

Semantic memory. In the word fluency test, a semantic memory task, three sets of words were generated, each set starting with a letter of its own. The sets were: words, five-letter words and professions (Nilsson et al. 1997). Each set was given one minute to complete.

In the word comprehension task participants were presented with a list of 30 target words. Next to each target five other words were presented, one of which being synonymous to the target word. This task was a test of the noise impact on the general knowledge in semantic memory.

All the items assigned to episodic memory were encoded according to experimental condition (silence, road traffic noise, meaningful irrelevant speech) but always tested for in silence at the end of the session. All the semantic memory tasks were performed according to experimental condition. The memory test items were assigned in advance to the latent variables episodic and semantic memory.

First- and second-order factors.

Nyberg et al. (2003) formulated and tested SEM for parts of the memory test battery in the Betula study. As several of our tests have a close similarity to the tests in the Betula study, we followed some of the SEM ideas in Nyberg et al. (2003). First- and second-order factors were identified for model testing. As seen in Figure 1, recall and recognition were identified as first-order factors for episodic memory, and knowledge and fluency for semantic memory. In the Betula study or in the test battery analyzed by Nyberg et al. (2003), there was no test for a text. Thus, in addition to Nyberg et al. (2003) Text was introduced a latent variable of its own in out SEM.

The statistical testing strategy followed was basically the same as in Nyberg et al. (2003). Initially one matrix across all age groups and noise conditions was tested against competing structural models, with and without 2nd-order factors.

In Enmarker et al. (2006) model fit was evaluated by examining the χ^2 and mean-square error of approximation (RMSEA; Browne & Cudeck 1993), comparative fit index (CFI; Bentler 1990), and non-normed fit index (NNFI; Bentler & Bonnet 1980). Priority was given to the RMSEA criterion, following the suggestion by Browne and Cudeck (1993) that a RMSEA about .08 or less is a reasonable fit, and about .05 or less is a good fit.

See Figure 1 for the SEM, standardized loadings, and free error covariances between items.

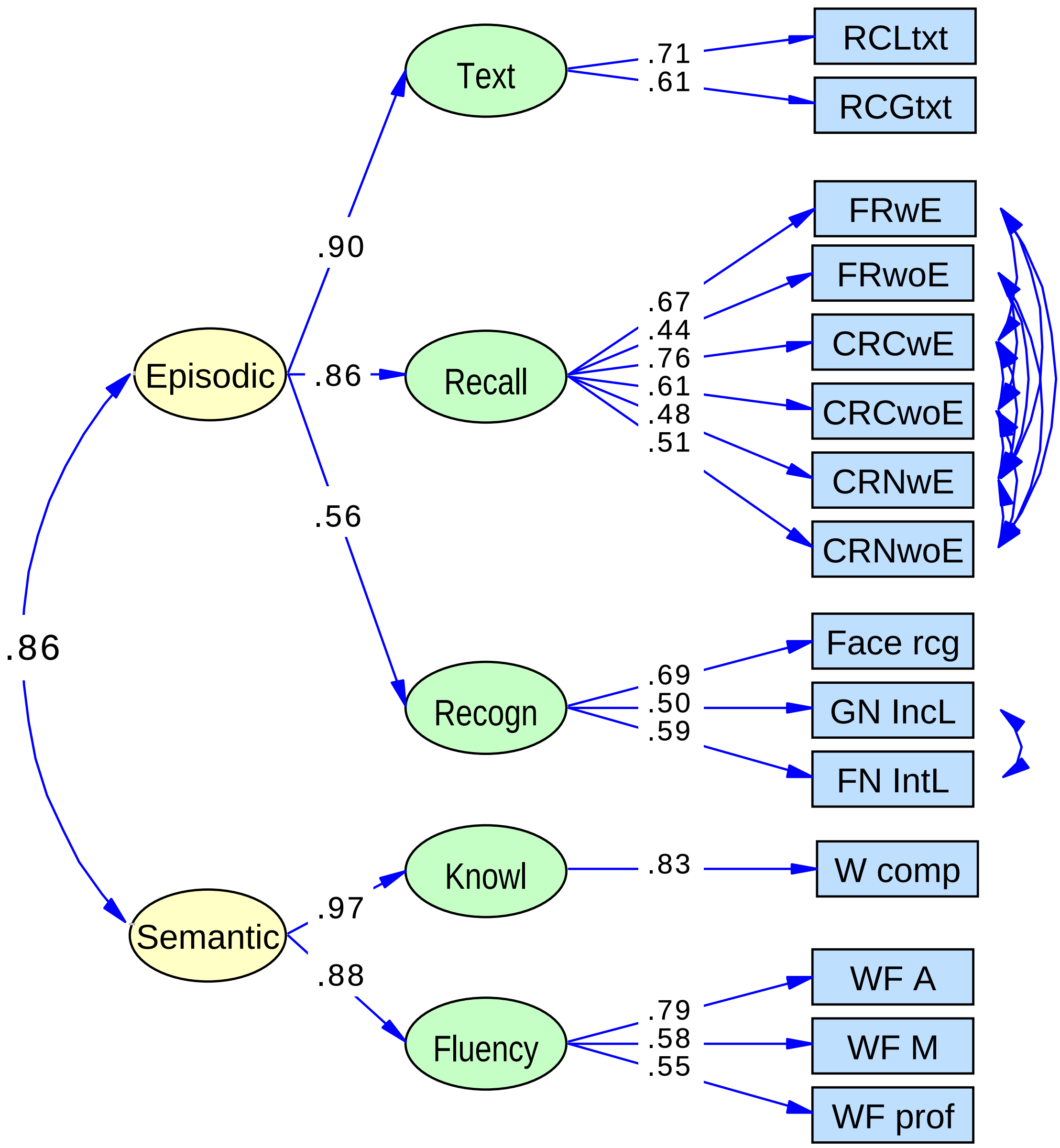

Figure 1: Conceptual diagram of a model for a single sample with the addition of a separate first-order factor (Text) for the text memory items (RCLtxt, RCGtxt) loaded on the second-order factor Episodic, with the corresponding indicators, standardized loadings, and free error covariances ($\chi2$ = 90.17, *df* = 74, *p* = 0.097, *RMSEA* = 0.028). In all cases the standardized latent variable–item coefficients were significant (all *t*s > 4.03, all *p*s < 0.001), and none of the items had a higher standardized latent variable–item coefficient when loaded on another latent variable than the one hypothesized.

Mediation models. Figure 1 depicts a good model fit for the single sample where age groups and noise conditions are collapsed. However, follow up tests of that model indicated that quite the youngest age group (13-14 years) did not abide to the general model.

Also, the model presented in Figure 1 did not include Noise as a latent variable, nor was there any attempt to model mediation between the latent variables.

As the youngest group stands out it would be interesting to find out whether there is any mediation model that applies to the youngest age group and another model that applies to the older groups. One way to approach this is to formulate and test alternative models to see whether some of the models show a good fit with data for the young ones and another model for the older groups. Comparing the models could then give some insight into which kind of developmental change that with growing cognitive maturity and whether noise exposure has any impact.

Five models were chosen for further testing. They are depicted in Figure 2. With the exception of model 4, they all have the latent variable Text as a last chain in the mediation link, and with the other variables as mediating or moderating links. Model 4 differs from the other models in the respect that it does not include any element of mediation, and thus may serve as an independence base line.

The strategy was to compare the five models under three restrictions: (1) with all four age groups included, (2) with the youngest group (13-14 years) excluded, and (3) only with the youngest age group. Models that show a good fit with data under restrictions 2 or 3 may be viable candidates for theorizing about what is equal and what is different between the youngest group and the older groups.

In the model testing the error covariances were set free between the same pairs of item as in Figure 1.

RESULTS

In evaluating the outcome of the model fit only the RMSEA criterion was employed. A RMSEA about .08 or less is taken a reasonable fit, and about .05 or less as a good fit (Browne & Cudeck 1993).

The results of the comparison between the models are shown in Table 2. As can be seen the mediation chains with only complete mediation from Noise by Semantic by Episodic to Text (Model 1) may be satisfactory for the age groups 18-20 years and older, but not for the youngest groups. For the youngest group there is a somewhat better fit with Model 2 where Episodic precedes Semantic in the mediation chain.

Model 3, in which Noise only influences Text has some merit to it, both in the youngest group by itself and also in all age groups from 18-20 years and older.

Model 4, the independence model does not rate well, neither with the youngest group, nor with the age groups from 18-20 years and older.

The fit for Model 5 is about as good as for Model 3. That is, which is in contrast to Model 3, that Noise may have a direct influence on both Semantic and Episodic, but no direct path to Text. This model has about the same goodness of fit both for the youngest group and for the age groups from 18-20 years and older.

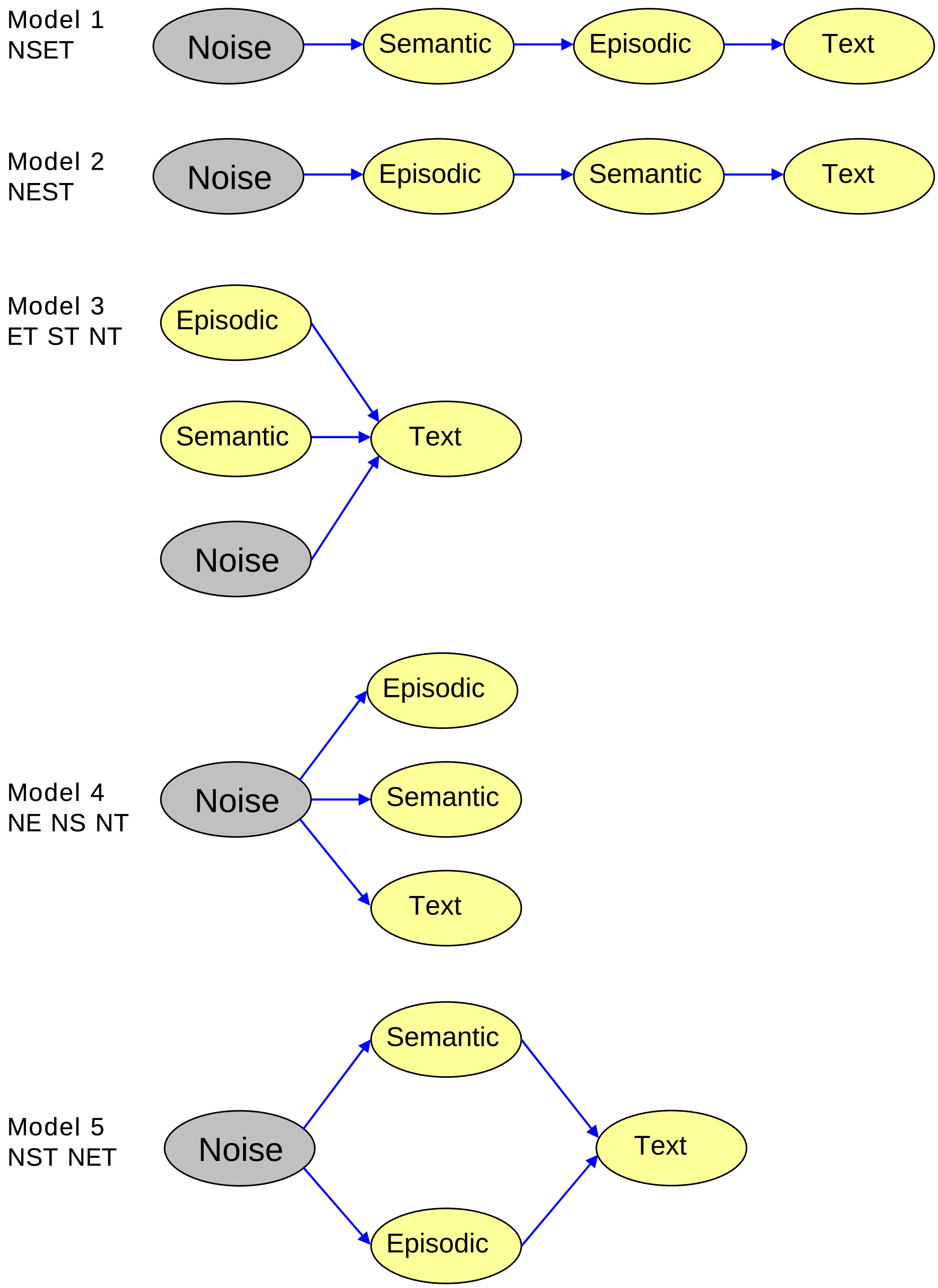

Figure 2: Mediation models for testing

Table 2: *RMSEA*-values and *df*s for the five conceptual models with the youngest age group included, excluded, and as a separate group

Model	All age groups (*df*)	Not age group 13-14 years (*df*)	Only age group 13-14 years (*df*)
1 NSET	.081 (499)	.053 (363)	.084 (91)
2 NEST	.079 (499)	.062 (363)	.055 (91)
3 ET ST NT	.073 (497)	.046 (361)	.051 (89)
4 NE NS NT	.081 (499)	.061 (363)	.074 (91)
5 NST NET	.078 (498)	.053 (362)	.051 (90)

CONCLUSIONS

The models that came out relatively best on best models in our tests were number 3 and 5. What this implies is maybe better stated in terms of which theoretical models that were not given support, numbers 1, 2, and 4.

Model number 1 and 2 is in terms of one single chain of mediation, with Noise as a start and Text as the end product. The short-coming of these models indicate that there is no simple full mediation from Noise to Text by Semantic and Episodic, or the last two in reversed order. Further, Model 3, assuming no interdependency or mediation between Semantic, Episodic, and Text, also is not the best of our models. Thus, what remains is a kind of partial mediation model. Models number 3 and 5 are such models.

Although there are only 96 persons in age group 13-14 years (32 in each noise condition), and a summed total of 192 in the other age groups, the RMSEA-value, which will be lower with a lower *N*, for the youngest groups is not substantially lower for the other age groups combined.

In Enmarker et al. (2006) it was noted that noise from meaningful irrelevant speech does not produce any appreciable shift in the covariance matrix as compared to the matrix when exposed to road traffic noise, or for that matter, in the quiet condition. A direct two sample test involving only the Road traffic noise group and the Speech group, with the same restraints as in Figure 1, showed good agreement between the two (χ^2 = 209.40, *df*=193, *p*=0.199, RMSEA=0.030). Thus, in this respect speech is not special (Lieberman, 1982). However, this was not tested separately for the youngest age group.

Thus, the SEM memory problem with the young group may lie somewhere else than in how our conceptualization of how the latent variables Episodic, Semantic and Text interact. It may be the case that the two different noise conditions, road traffic noise and irrelevant speech have their own differential effects on semantic and episodic memory for children, which may be in a developmental transition state, and which were not properly modeled in the latent memory structure models we have tested here.

As a strengthening argument for the validity of our findings on the noise invariant memory structure, it should be borne in mind the quite satisfactory goodness-of-fit measures were obtained without excluding the youngest age group, which according to the age invariant analyses stands out from the other age groups on latent memory structure.

In summary, we have shown that some of the possible meditational models of how noise influences episodic and semantic memory and text reading for children can be ruled out. What remains to be analyzed is whether speech noise and road traffic noise tap different or similar memory capacities for children as for adults.

However, how that should be put to scrutiny is a future story.

REFERENCES

Bentler PM (1990). Comparative fit indexes in structural models. Psychol Bull 107: 238-246.

Bentler PM, Bonnet DG (1980). Significance tests and goodness-of-fit in the analysis of covariance structures. Psychol Bull 88: 588-600.

Browne MW, Cudeck R (1993). Alternative ways of assessing model fit. In: Bollen KA, Long JS (eds.): Testing structural equation models. London: Sage.

Engelkamp J (1995). Visual imagery and enactment of actions in memory. Brit J Psychol 86: 227-240.

Enmarker I, Boman E, Hygge S (2006). Structural equation models of memory performance across noise conditions and age groups. Scand J Psychol 47: 449-460.

Hygge S, Boman E, Enmarker I (2003). The effects of road traffic noise and meaningful irrelevant speech on different memory systems. Scand J Psychol 44: 13-21.

Liberman AM (1982). On finding that speech is special. Am Psychologist 37: 148-167.

Nilsson L-G, Bäckman L, Erngrund K, Nyberg L, Adolfsson R, Bucht G, Karlsson S, Widing M, Winblad B. (1997). The Betula prospective cohort study: Memory, health, and aging. Aging Neuropsychol Cogn 4: 1–32.

Nyberg L, Maitland SB, Rönnlund M, Bäckman L, Dixon RA, Wahlin Å, Nilsson L-G (2003). Selective adult age differences in an age-invariant multifactor model of declarative memory. Psychol Aging 18: 149–160.