Shifting Novices' Mental Representations of Texts Toward Experts': Diagnosis and Repair of Novices' Mis- and Missing Conceptions

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Abstract[1]

The shape of the memory representation for a 1000 word text was measured for the text's author, 7 independent subject matter experts and 2 groups of novices (N = 83 Air Force recruits). To measure the shapes, we chose the 12 most important concepts from the text, and then collected proximity data on all possible pairs of them. Then we made maps of the mental representations from the proximities. In Experiment 1, results of empirical tests of text learning showed that the novices' mental representations after reading the Original Version of the text were correlated only +.1 with the author's or experts' representations. But for a Principled Revision the correlations were above +.5. In Experiment 2, the proximity data from Experiment 1 were used to diagnose specific misconceptions and missing conceptions in both the Original text and the Principled Revision. This revealed unsuspected cognitive misconceptions, as well as intrusions of affective and attitudinal factors into the novices' mental representations. These diagnoses were then used to revise both texts to repair the misconceptions and insert the missing conceptions. Results of empirical tests of these revisions (N = 160 Air Force Recruits) showed that novices' correlations with the author's and experts' representations were shifted close to ceiling (r = +.8 - + .9). These results show that novices' mental representations can be shifted to correspond with experts by using our methods to diagnose and repair mis- and missing conceptions.

The "shape" of the memory representations that are created by texts was investigated. By "shape" we mean the configuration of relations between the concepts in the text. The shape is measured by asking subjects to rate the relatedness of all possible pairs of important concepts from the text. This yields a set of proximity measures (i.e., distance measures), which are used to construct a graphic representation or map of the underlying mental structure. The map represents the shape of the reader's memory representation. We compare each reader's structure to the structure intended by the text's author and qualified experts in the subject matter. The result provides a quantitative measure of the goodness-of-fit of the readers' structure to the expert structure. Since this test measures cognitive structures, we will call it the Cognitive Structure Test.

Experiment 1: Comparing the Mental Representations of Novices, Experts and the Text's Author

We measured the shape of mental representations for a text by collecting proximity data on the important concepts in a naturally occuring 1000 word text on Air Force history (Earhart, 1978).

Method

The proximity data were collected as follows: (a) Two judges chose the 12 most important concepts from the text. (b) Then all possible pairs of the 12 concepts were constructed - 66 in all. (c) Since these pairs represent all possible relations between pairs of important concepts in the text, they should capture all the relations between important concepts, and closely approximate a collection of all the important relations in the text. (d) Proximity data were

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of Military Strategy, Military Advisers, and furthest away, Success. Those familiar with this period of history, or who have read the passage, (available from the authors) will recognize this representation.

Experiment 2: Diagnosing and Repairing Mis- and Missing Conceptions by Revising the Text

In this study we successfully used these proximity data to revise the Air Force Vietnam text, greatly improving the goodness-of-fit of novices' mental representations to the author's and experts' representation. For expository effectiveness, we report the results first, and then the revision method. Table 2 shows the results. The entries at the left replicate the results in the two rows of Table 1.

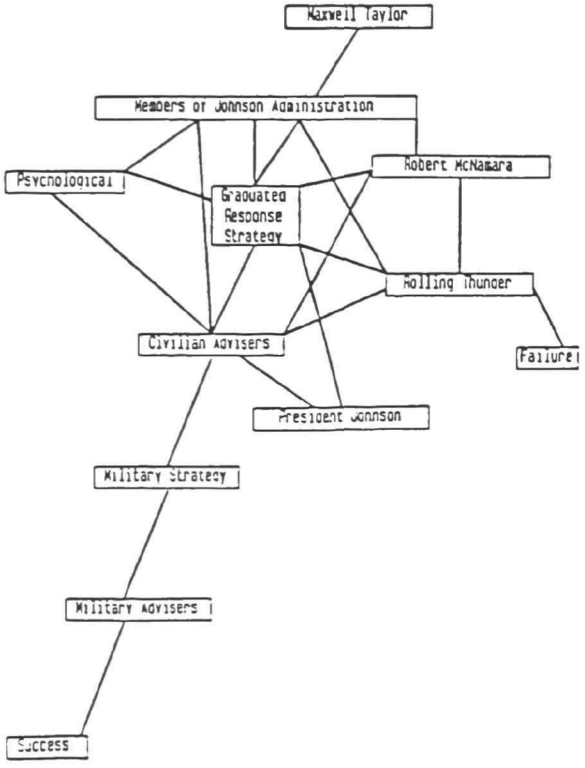


Figure 2 - Experts' Pathfinder Network

The revisions were done in 5 sentences (of 43 sentences in all) of the Original and Principled Revisions. The entries at the right of Table 2 show that these revisions had very large positive effects on the novices' correlations with the author's and experts' structure. These correlations were so close to the reliability of the Cognitive Structure Test that a ceiling effect is probably present. These results show that our techniques can be used successfully to shift novices' mental representations toward experts'.

How did we use the proximity data to decide which revisions to make?

To know what to revise in the text, we needed to know: (a) what novices knew correctly after they read the text; i.e., what correct conceptions they had; but more importantly (b) what they knew that wasn't so; i.e., what misconceptions they had after reading the text; and (c) what they didn't know after reading; i.e., what missing conceptions they had.

Table 2

Correlations of Four Recruit Groups with Author's and Experts' Structures on Cognitive Structure Test

	Original Version	Principled Revision	Original Version with 5 Revision	Principled Version with 5 Revision
Author	.18	.59*	.80*	.86*
Experts	.22	.62*	.87*	.86*

*$p < .05$, different from its control

To get this information, we further analyzed the cognitive structure data from Experiment 1. When we looked at the novices' network structure for the Original Version (Figure 3, built from the proximity data using Pathfinder (Schvaneveldt, 1990)) we were unable to interpret it plausibly. So we began to believe that the Original group might contain several subgroups, each with a somewhat different mental representation. If Figure 3 was those different representations superimposed on each other, the result would be a composite of different structures rather than a true representation of the central tendency of the Original group.

So, using factor analysis, we looked for subgroups in each condition who were correlated with each other. Then we took each subgroup's subjects, and looked at their structure. These structures were much more interpretable, and we derived our revisions from them for the present study.

Identifying subgroups by factor analysis. We proceeded as follows: (a) For the 46 subjects who read the Original Version, we took each subject's vector of 66 responses, and correlated it with the vector of each other subject who read the Original Version. This produced a large correlation matrix, showing which subjects were correlated with each other. (b) We then factor analyzed this matrix, using the individual subject as

collected by having each subject rate the "relatedness" of each pair of concepts on a seven-point scale, ranging from "very closely related" to "very distantly related" (N=83 Air Force Recruits). This is the Cognitive Structure Test. (e) With proximity data for all pairs of entities, a map can be made of the configuration of relations between the entities, using any of a variety of algorithms; we chose network analysis (Schvaneneldt, 1990).

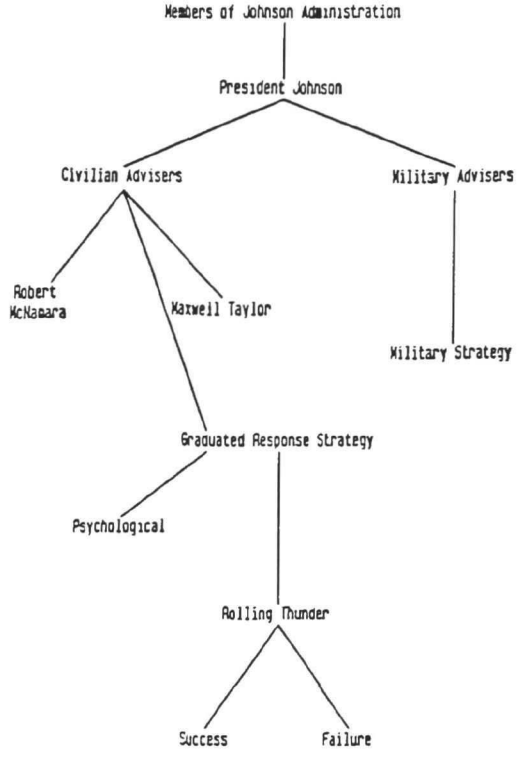


Figure 1 - 12 Terms Used in Test

These proximity data were collected from novices for two different versions of the text: The Original version and a Principled Revision (derived from the Original using the Kintsch and Van Dijk (1978) model, as described in Britton & Gulgoz, (in press) available from the first author). The same Cognitive Structure Test was also given to the text's author (a History Professor at the Air Force Academy), and to seven independent experts on the text's subject matter (an ambassador, three military historians, etc.)

The 12 Terms. To clarify the character of the test, the content of the passage is here described briefly with the terms used in the test arranged graphically in Figure 1 and underlined here. (Figure 1 was not shown to the subjects). The texts began by describing some members of the Johnson Administration, including President Johnson, who had civilian advisers, including Robert McNamara and Maxwell Taylor, as well as military advisers. The military advisers proposed the military strategy, which was to bomb North Vietnam very heavily. The civilian advisers proposed instead the graduated response strategy, which was to bomb North Vietnam a little and then pause to see if that had "broken their will"; if it hadn't, the bombing would be escalated gradually. Since the focus was on breaking the North Vietnamese will, this was described in the passage as a psychological strategy. Johnson chose the graduated response strategy, and the resulting operation was code-named Rolling Thunder. Success and failure could be attributed to the various persons, policies, actions, and consequences in the passage.

Results and Discussion

The recruits' 66 ratings of relatedness were correlated with those of the author and experts. Results showed that : (a) the author's and expert's representations were inter-correlated +.8, indicating they all had similar representations; (b) recruits who read the Original version correlated only +.10 with the author and experts (Table 1, column 1); and (c) recruits who read our Principled Revision correlated above +.5 with the author's and experts' representations, indicating that the Revision had improved the quality of their mental representation (Table 1, column 2), where "improved quality" means closer correspondence to the author's and experts' representation.

Table 1

Correlations of Two Recruit Groups with Author's and Experts' Structures on Cognitive Structure Test

(Author and Experts read Original Version)

	Original Version	Principled Revision
Author	.08	.52*
Expert	.10	.55

*$p < .05$, different from Original

Figure 2 shows the network structure created from the average experts' proximity data by the Schvaneveldt Pathfinder program. It has the Graduated Response Strategy in the center, surrounded by a starlike pattern composed of: (a) the various persons involved in that strategy: President Johnson, Robert McNamara, Maxwell Taylor, Members of the Johnson Administration, and Civilian Advisers; (b) its main characteristic -- that it was Psychological; and (c) its consequence -- Rolling Thunder, which was a Failure. Toward the periphery of the representation are the notions

the unit of analysis. The result was that we ended up with 3 subject factors (i.e., each factor was inhabited by a number of subjects). (The Scree test was used to select the number of factors; a standard varimax rotation was then used; subjects who loaded above +.40 on a factor were considered to be inhabitants of that factor.) (c) The subgroup of subjects who loaded above +.40 on any factor were then segregated from the rest of the subjects, into a factor of their own. (d) Then for each factor separately, we averaged the subgroup of subjects' responses for each item, producing an average vector for that factor, 66 items long, representing the cognitive structure characterizing that factor. (e) We also did steps a through d for the 37 subjects who had read the Principled Revision. (f) We now had the mental structure for each subject factor, for six factors in all, including three factors for each text.

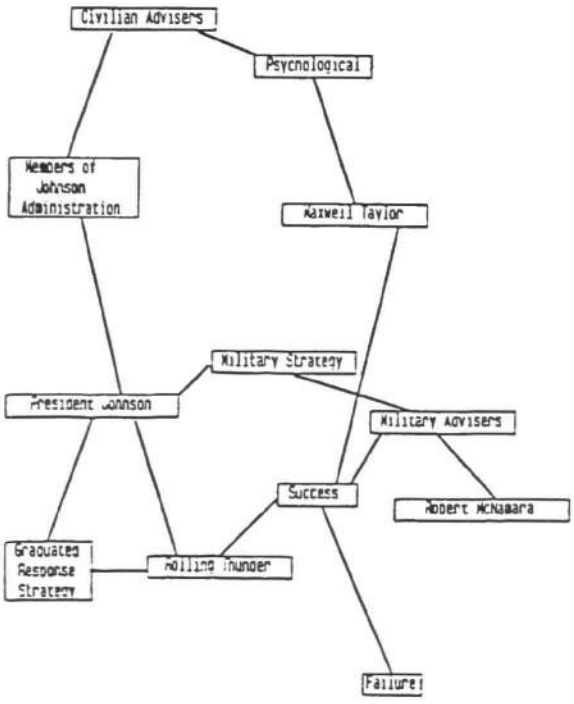


Figure 3 - Original Version Readers' Pathfinder Network

The next question was: What knowledge structures do these factors represent? The first answer was easy: surely some factors must be similar to the author's or experts' structure. To test this, we correlated the string of 66 numbers for each factor with the author's and experts' structure, yielding the results shown in Table 3.

Table 3

Correlations of Factor Scores in Groups with Author and Experts

	Original Version			Principled Revision		
	Factors			Factors		
	1	2	3	1	2	3
	n=14	n=12	n=9	n=12	n=11	n=6
Author	-.10	.17	.47*	.77*	.35*	-.15
Experts	-.10	.21	.50*	.77*	.41*	-.18

*p < .05, different from r = 0.

It was no surprise that the author's and experts' structure was found as Factor 1 --the largest factor-- in the Principled Revision. But we also found the experts' structure as Factor 3 in the Original Version, albeit as the factor with the smallest number of subjects of the three factors. Moreover, those two factors -- the two correlated with the author and experts -- were also highly correlated with each other (i.e., Original Factor 3 and Principled Factor 1 were correlated +.76 with each other) indicating that both of those factors had approximately the same pieces of the author's and experts' structure.

Identifying misconceptions and missing conceptions. What we needed to know in order properly to revise the text for the subjects in any factor was this: On which concepts did they deviate greatly from the experts' structure? Those concepts would represent misconceptions, or missing conceptions, and these we should specifically address in our revision, in order to repair those novices' faulty representations.

We identified each factor's mis- and missing conceptions by dividing each factor's string of 66 numbers into 12 equal parts. Each part represents the structure for one of the 12 concepts. Figure 4 shows this graphically for one concept on which the subjects in Factor 1 of the Principled Group were very similar to the experts (Graduated Response Strategy), and Figure 5 shows it for one concept on which Factor 3 of the Original Group was dissimilar to the experts (McNamara). (These figures have the 12 terms abbreviated along the side, and the rating scale that subjects used is shown along the bottom. Each plotted point represents the average relatedness rating between the term shown in the title of the figure and the corresponding term along the side. Missing in each figure is the relatedness rating between the term in the figure's title and itself.)

The first two panels in each figure show the pattern separately for the experts and the novices; the third panel shows the patterns superimposed to show the similarity and

Figure 4
Cognitive Structures for "Graduated Response Strategy" in Expert Group and Factor 1 of Principled Revision Group; Superimposition Shows Similar Conceptions

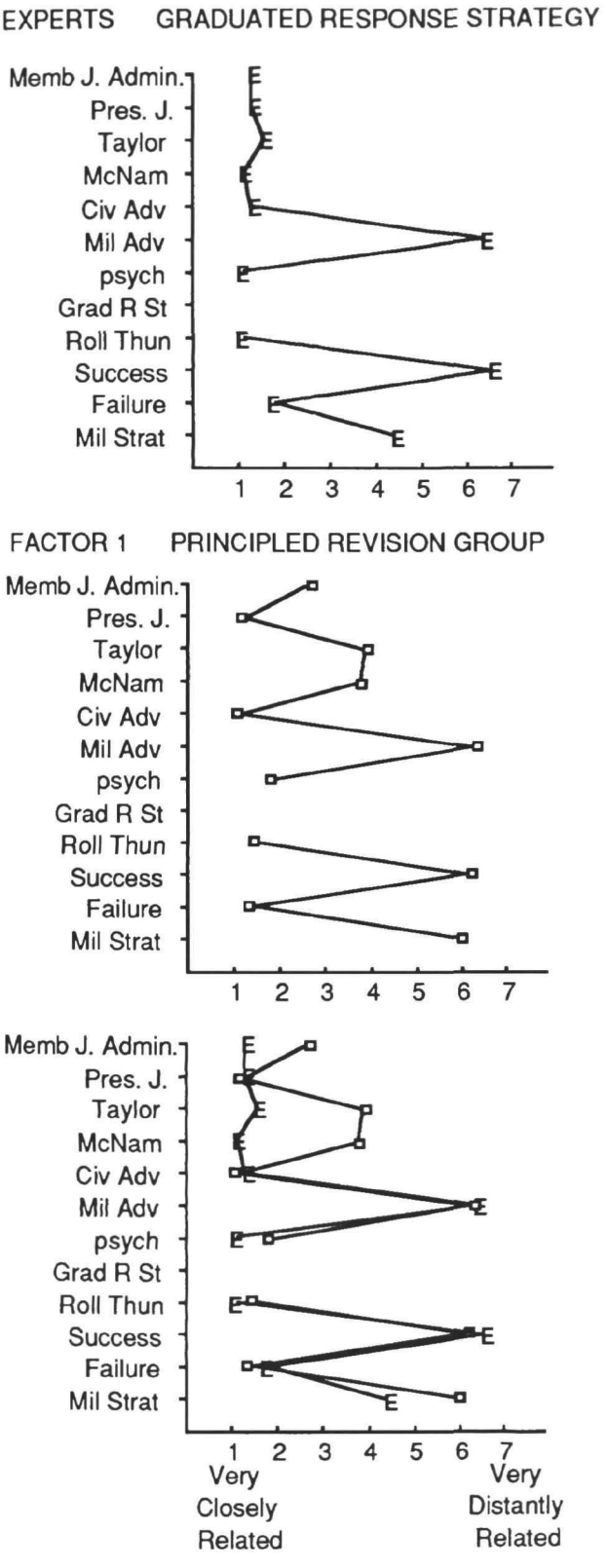
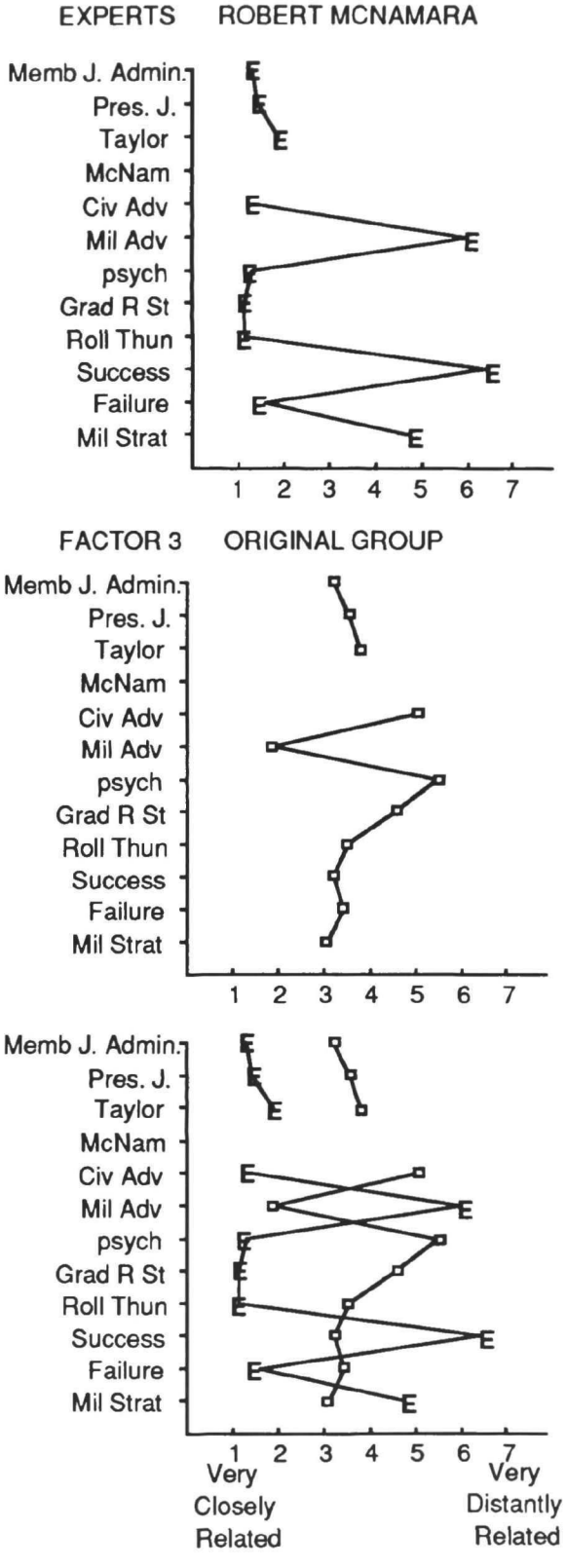


Figure 5
Cognitive Structures for "Robert McNamara" in Expert Group and Factor 3 of Original Group; Superimposition Shows Dissimilar Conceptions



dissimilarity, respectively. The correlation between novices and experts (n=11 terms) for Graduated Response Strategy was +.87, for McNamara it was -.66. Obviously, these subjects have misconceptions about McNamara. Moreover, we can read off the figures what those misconceptions are.

The results of all 12 of these analyses showed that the novices' representations for McNamara and for Taylor were grossly discrepant from the experts'. So for our revisions we chose sentences mentioning those two terms.

Our analysis of all the factors in Table 3 proceeded in the same way. The recruits in two of the factors (one factor in each group) thought the whole operation was a resounding success, perhaps revealing an intrusion of affective and attitudinal factors due to these recruits being in their eleventh day of Air Force Basic Training. So the terms "success" and "failure" were also chosen for revision to help this group of novices with their representations. The final two factors indicated additional misconceptions for "military advisers" and "civilian advisers," and so the sentences involving those terms were also revised accordingly. As it turned out, all these revisions could be done in 5 of the 43 sentences in the text. The results of that study have been shown in Table 2.

Conclusions

These studies show that novices' representations can be shifted toward experts' by repairing novices' mis- and missing conceptions. This was done by using the Cognitive Stucture Test to identify mis- and missing conceptions. A side benefit is that the problematic conceptions can be specified at a grain size that is the same as the grain size of appropriate revisions, i.e., at the grain size of text sentences that mention the concepts. This technology for improving instructional texts appears to be widely applicable.

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