TRANSFER APPROPRIATE PROCESSING (TAP),
THE SEMANTIC DIFFERENTIAL
AND MEANING PRIMING

By

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CHAPTER I

INTRODUCTION

Implicit Priming and TAP

Priming is facilitation or bias in performance resulting from past experiences. It is often manifested as faster response times, improved accuracy or bias towards one response over another. Implicit priming happens when people show facilitation or bias in performance while they are not aware of the facilitation or bias from prior experiences (Roediger, 1990; Roediger & McDermott, 1993; Schacter, 1987; Shimamura & Squire, 1984). In word stem studies subjects often showed greater than chance probability of responding with words they had seen in the study phase, independent of whether or not they could recall or recognize the words as being in the study phase.

Implicit memory as reported in the present study emphasizes more the unawareness of facilitation or bias rather than the unawareness of prior experiences. For example, in degraded word identification tests subjects might be faster at identifying old words from the study phase but be completely unaware of the savings in response times, as the savings were often less than 50 ms. The facilitation in response time was regarded as implicit priming even if subjects could recognize the words as being in the study phase. The priming was implicit in that it happened independent of subjects' explicit knowledge about the priming.

Implicit memory has been treated as having two categories, perceptual and conceptual implicit priming. Tests for studying perceptual implicit memory are well developed, such as word stem completion, perceptual identification, anagram solving and lexical decision (Roediger & McDermott, 1993; Schacter, 1987). Greatest priming was found when test stimuli were identical as the acquisition stimuli and less or no priming when they differed in modality, presentation format (word vs. picture), or even font type and letter case. On the other hand, although various tests, such as word association, category instance generation, and answering general knowledge question, were tried for testing conceptual implicit memory, few has been widely accepted because of inflated possibility of explicit memory contamination. Acknowledging the possible confound, the results generally showed that conceptual implicit priming was affected by manipulations of meaning but not perceptual similarity of study and test events.

Successful retrieval depends on stimuli and processing match between retrieval and acquisition for explicit memory (Bransford, Franks, Morris & Stein, 1979; Morris, Bransford & Franks, 1977; Tulving, 1979). The Transfer Appropriate Processing principle (Bransford et al.; Morris et al.), originally proposed for studying explicit memory has been employed to study perceptual implicit priming effects

(Blaxton, 1989; Roediger & McDermott, 1993; Schacter, 1987). According to TAP, the specific processing of specific stimuli will facilitate later processing of the same stimuli, to the extent that the earlier and later events have overlapping processes. TAP differs from the Encoding Specificity Principle (Tulving, 1979) in that it emphasizes match of the dynamic processing on acquisition and retrieval stimuli besides acquisition and retrieval stimuli per se.

TAP was recently used to guide exploration of conceptual priming effects as well (Franks, Bilbrey, Lien & McNamara, 2000; Vriezen, Moscovitch & Bellos, 1995). Vriezen et al. suggested that conceptual priming was determined by the overlap in component processes of study and test tasks. Processes on word or pictorial stimuli were hierarchically arranged, from the lower level processing of lexical decision to higher level semantic processing. Higher level processes were at a later stage of processing and required the completion of certain lower level processes. Processing at later stage would prime early processing of the same stimuli but not in the other direction.

Experiments in Franks et al. (2000) involved an acquisition phase and two test phases. Subjects made a certain judgment such as *big/small* on words at acquisition. During test phases subjects also made judgments on words; the judgment could be either the same as, or different from, that in the acquisition. If during test subjects were faster at processing old words from the acquisition task than new words, there's said to be repetition priming (RP) effects, also referred to as transfer. The priming effects were termed repetition priming effects because they involve the same word stimuli (Roediger, 1990). Maximum RP effects were observed when the acquisition and test involved the same judgment task. When the acquisition and test task differed the results were mixed. Symmetrical RP was found between *big/small* and *hard/soft* judgments, i.e., making *big/small* judgment on words facilitated the later processing of *hard/soft* judgment on these words, and vice versa. Symmetrical RP was also found between *lexical decision* and *like/dislike*. Asymmetrical RP patterns were found between *hard/soft* and *like/dislike*, *e-check* and *lexical decision* judgments. There was significant RP from, *hard/soft* to *like/dislike*, *e-check* to *lexical decision* and less or no transfer in the opposite direction. The stage-of-processing theory suggested by Vriezen et al. (1995) could explain priming in most of the conditions but encountered difficulty when explaining the priming from *like/dislike* and *e-check* to *lexical decision*.

Franks et al. (2000) explained the results with automatic processing effects. They argued that while subjects were explicitly making a certain judgments, they also might in some cases automatically make other judgments. When the automatically elicited judgments matched the intentional test judgments, it would facilitate test processing. For example, when subjects were doing the *hard/soft* judgment, they might be automatically processing some other judgments such as *like/dislike*. When they were later asked to do a *like/dislike* judgment, there would be RP effects.

A basic question in implicit memory is what is the structure of memory that mediates such RP effects. It is possible to use the TAP principle to empirically map out the relationships between various judgments, thereby reveal the structure of the implicit memory space post hoc from the experiment results. However, the range of selection of judgments is unlimited and random selection of tasks is very ineffective. Some methodological strategy regarding the relationship between various judgments is needed. A potential heuristic involves the semantic differential. The semantic differential was originally proposed by Osgood, Suci and Tannenbaum (1957) as a framework to measure meaning. The semantic space can be viewed as a memory construct by which information is encoded, stored and retrieved. The guiding hypothesis of the present study is this semantic space may mediate RP patterns between semantic judgment tasks.

The Semantic Differential

According to Osgood et al. (1957), the semantic space could be defined by a series of orthogonal semantic dimensions. A word in the semantic space was similar to a point in 3-dimensional Euclidean space. Every semantic scale, as indicated by polar terms such as *good/bad* and *large/small*, was assumed to represent a straight line in the semantic space. Appropriate scales representing each dimension formed axes of the semantic space.

Osgood et al. (1957) used factor analysis on correlations between semantic scales to isolate and identify major dimensions of semantic space (see Appendix A). The first three most prominent factors (dimensions) were identified as the Evaluation, Potency and Activity factors in order of the proportion of variance accounted for. Typical scales of the E dimension were *good/bad*, *kind/cruel*, and *ferocious/peaceful*. Typical scales of the P dimension were *large/small* and *strong/weak*. *Fast/slow* and *sharp/dull* were representative of the A dimension. Additional factors were extracted in following studies but the most prominent ones remained E, P and A (Bentler & LaVoie, 1972; Tzeng, 1975; Tzeng & May, 1975; Wickens & Lindberg, 1975).

The Hypothesis

The meaning of a word varies multidimensionally in the semantic space. Something judged good may also be judged strong (for example, HERO). If the judgment scales fall on orthogonal dimensions, they are assumed to be independent of each other. Being good is independent of being strong, and vice versa. In relation to the TAP principle, for present purpose it is assumed that there is no overlapping process between the *good/bad* and *strong/weak* judgments. On the other hand if the judgment scales have significant projections to the same semantic dimension(s), there is assumed to be overlapping processes between them. For example, *big/small* and *hard/soft* both have significant projections to the P dimension

(Osgood et al., 1957). In the Franks et al. (2000) study, symmetrical RP was found between *big/small* and *hard/soft*, indicating overlapping processes between them.

The hypothesis in the present study is if judgment scales project to orthogonal semantic dimensions, i.e. loaded mainly on semantic factors orthogonal of each other, there will be little or no RP effect between the judgment tasks even though they are performed on the same word stimuli. In contrast if the judgment scales have significant projections to the same semantic dimension(s), i.e. have significant loadings on the same semantic factors, there will be RP effects when they are performed on the same word stimuli. For example, *pleasant/unpleasant* is mainly an E dimension judgment, with a loading of 0.82 on the E factor, and 0.28 on the A factor. *Fast/slow* has a loading of only 0.01 on the E factor, but 0.70 on the A factor (all semantic factor loadings and communalities cited in this paper were from *Analysis I*, Osgood et al., 1957 unless otherwise noticed. Part of the results in *Analysis I* was shown in Appendix A). We should expect little or no RP when these two judgments are crossed. *Young/old* has equivalent loadings on both the E and A factors, 0.31 and 0.32 respectively. We should expect some RP effects from *young/old* to both *pleasant/unpleasant* and *fast/slow* judgments.

CHAPTER II

GENERAL METHODS

Subjects

Subjects were students in undergraduate psychology courses in Vanderbilt University who participated in the experiments for experimental credits. They had normal or corrected-to-normal vision. All subjects signed a consent form to participate in the study.

Design

The basic experimental design was a 2(acquisition task) x 2(test task) x 2(item type) mixed design as illustrated in Figure 1. It was the same design as in Franks et al. (2000).

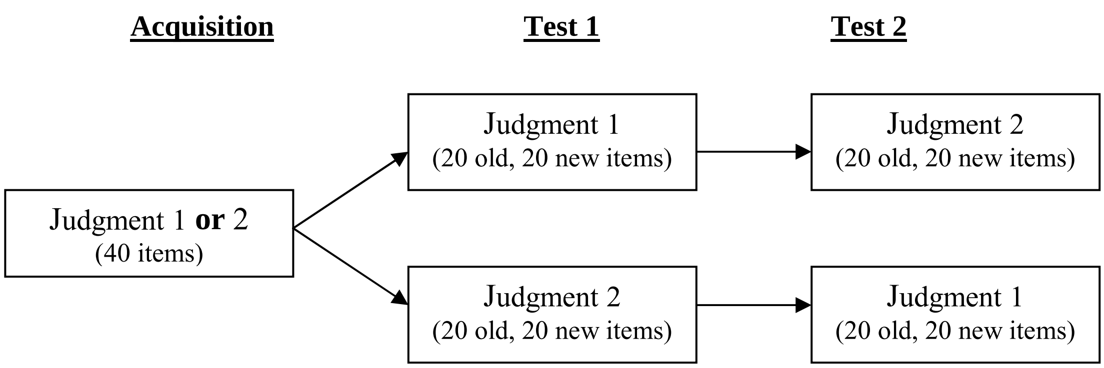

Figure 1 General Experimental Design

The basic design was consisted of an acquisition phase and two test phases. The acquisition judgment tasks and the order of test judgment tasks (same vs. different) were counterbalanced across subjects. There was a brief break (30sec) after each phase.

Materials

Semantic scales were used for the acquisition and test judgment tasks. For example, in *strong/weak* judgment, subjects decided whether an item referred to something *strong* or *weak*. Scales were selected according to a comprehensive consideration of three study results, The Rotated Factor Loadings--Analysis I, Rotated Dimension Coordinates--Analysis II, and Unrotated Square Root Factor Analysis--Thesaurus Study (Osgood et al., 1957). Scales representing orthogonal dimensions had significant loading mainly on their corresponding factor and little loadings on other orthogonal factors.

Some scales were chosen to be intermediate, in which case they had significant loadings on both orthogonal factors under consideration.

Table 1 Scales Used in the Experiments and Their Loadings on the E-P-A Factors

	Analysis I			Analysis II			Thesaurus Study		
Semantic Scale	**E**	**P**	**A**	**E**	**P**	**A**	**E**	**P**	**A**
pleasant/unpleasant	0.82	-0.05	0.28	2.38	0.56	0.24	-	-	-
strong/weak	0.19	0.62	0.20	0.38	1.81	0.67	0.30	0.40	0.10
fast/slow	0.01	0.00	0.70	0.42	1.10	1.50	0.01	0.26	0.35
active/passive	0.14	0.04	0.59	0.30	1.64	1.39	0.17	0.12	0.98
young/old	0.31	-0.30	0.32	1.22	0.83	1.26	-	-	-
valuable/worthless	0.79	0.04	0.13	1.87	1.12	0.25	-	-	-

- *The Measurement of Meaning*, Osgood et al., 1957

Test items were chosen from *Semantic Differential Profiles for 1,000 Most Frequent English Words* (Heise, 1965), according to their eigenvalues on the relevant semantic factors. In each experiment there were 80 test items and 24 practice items, which could be divided equally into four subsets according to the relevant judgment scales in that experiment. For example, if the judgment scales under study were *pleasant/unpleasant* and *strong/weak*, there would be an equal number of *pleasant* vs. *unpleasant* or *strong* vs. *weak* items, i.e. equal number of items that were *pleasant* and *strong*, *pleasant* and *weak*, *unpleasant* and *strong*, and *unpleasant* and *weak*. These subsets of items had the same average eigenvalue on corresponding semantic factors relative to the judgment scales involved. This was to minimize the influence of words on RP between judgment tasks. For example, the word STEEL loaded highly on the P factor, with an eigenvalue of 4.60. The word LAKE had an eigenvalue of only –0.22 on the same factor. It would be much easier/faster for subjects to judge STEEL than LAKE on the *strong/weak* scale. Test items for one of the experiments (Experiment 5, *pleasant/unpleasant* and *fast/slow*) were attached in Appendix B for reference.

There were 40 items in the acquisition phase, 40 in each test phases, and 8 in practice trials before each phase. Half of the items in each test phase were old items from the acquisition, and the other half were new. In each task, the number of items of each subset was equal. The item subset was counterbalanced across the old/new factors. Presentation order of items in acquisition and tests was randomized within subjects.

Procedure

Subjects were tested individually. Task instructions and materials were presented on 8088 personal computers in 80-column lowercase font. The instructions included examples and stated that there was no right or wrong answer in the tasks. Subjects were asked to respond soon as they had the impression of the meaning of words with regard to the judgment task instead of spending a lot of time thinking. Subjects read the instructions and were then presented words one at a time for judgment. They indicated different judgments by pressing the "z" or "/?" key on the keyboard (for example, "z" for *active* and "/?" for *passive* judgment). The dominant hand was assigned for "positive" judgments such as "*pleasant*", "*strong*", and "*fast*". Each trial began with a ready signal (*) that appeared in the middle of the screen for 500 ms. It was followed by the presentation of a word which remained on the screen until the subject responded. The interval from the previous trial response to the next ready signal was 1500 ms. Type of response and response time (RT) were recorded for each item.

Analysis

Subjects' RTs in all experiments were $\log_{10}$ transformed to normalize the data. The means of the log-transformed values were analyzed by 2-tailed t-tests. Priming effect was defined as the difference between RTs to new vs. old items, RT_{new} - RT_{old}. T-tests were performed on RPs as well as the main effect of tests whenever a within-subject comparison of tests was available. A mixed ANOVA test was also performed in Experiment 2. Mean RTs and priming effects reported in the experiments were transformed back from log values for reading convenience except in mathematical modeling.

CHAPTER III

EXPERIMENTS

Experiment 1

Experiment 1 examined whether there was RP between scales from the orthogonal semantic dimensions of E and P. According to hypothesis, no RP was expected.

Pleasant/unpleasant was selected as the scale representing the E dimension. *Strong/weak* was used as the P dimension scale. Sixty-four students participated in the study. They had either *pleasant/unpleasant* or *strong/weak* task at acquisition. They performed both tasks at test.

Very robust RP effects were found in the same-task transfer conditions. In accord with the hypothesis no RP effect was found in either cross-task condition, *pleasant/unpleasant* to *strong/weak* or *strong/weak* to *pleasant/unpleasant*. There was a significant within-subjects main effect of test tasks. Subjects were faster at the *pleasant/unpleasant* than *strong/weak* task, $F_{(1,62)}=20.88$, $P<0.001$.

Table 2 RP Effects between *Pleasant/unpleasant* and *Strong/weak* (ms)

task (1-2)	new items	old items	priming effects	t-score
p/u-p/u	947	820	127	6.17***
p/u-s/w	1058	1069	-11	-0.58
s/w-s/w	1103	939	164	6.08***
s/w-p/u	1032	1025	7	0.31

*** P<0.001

Experiment 2

Experiment 2 was designed to study the transfer pattern between P and A dimensions. Besides two scales representing the orthogonal dimensions, a third one was introduced as an intermediate task, i.e., it had significant loadings on both the P and A factors. No RP was expected between the two orthogonal scales, whereas some transfer was predicted for the intermediate scale to the other two scales.

Strong/weak and *active/passive* were chosen to represent the P and A dimensions respectively. *Fast/slow* was selected as the intermediate scale. Ninety-six students participated in the study. During acquisition they performed one of the three judgment tasks. All groups then performed both the *strong/weak* and *active/passive* judgment tasks at test phases.

The data was first analyzed by a mixed ANOVA test, with acquisition task as the between subject variable, test task and item type as within subject variables. Neither the within subject main effect of test task nor test task and item type interaction reached the significance level, with $F_{(1,93)}=3.33$, $P=0.07$ and $F_{(1,93)}=3.14$, $P=0.08$ respectively. The main effect of item type was then analyzed by multiple t-tests, results reported in table 3.

Table 3 RP Effects between *Strong/weak*, *Active/passive* and *Fast/slow* (ms)

task (1-2)	new items	old items	priming effects	t-score
s/w-s/w	1021	878	143	5.84***
s/w-a/p	997	982	15	0.63
a/p-a/p	988	896	92	5.16***
a/p-s/w	1085	1001	84	2.70*
f/s-s/w	1053	1025	28	1.56
f/s-a/p	1026	985	41	2.05*

*** P<0.001 * P<0.05

Greatest RP effects were found in same-task transfer conditions. An asymmetrical transfer pattern was found in cross-task conditions, with no significant RP from *strong/weak* to *active/passive* but some RP from *active/passive* to *strong/weak*. As to the intermediate task *fast/slow*, significant RP was found from *fast/slow* to *active/passive* but non-significant from *fast/slow* to *strong/weak*.

Contrary to the hypothesis, some RP was found from *active/passive* to *strong/weak* while no RP was found from *fast/slow* to *strong/weak*. One reason for this might be that *active/passive* was actually an intermediate scale for the P and A dimensions while *fast/slow* was the relatively pure representing scale of the A dimension. Although the E-P-A construct of the semantic differential is relatively consistent and reliable across studies, variabilities due to different subject population and concepts being scaled exist. *Active/passive* loaded more on the P rather than A factor in Osgood's Analysis II; *fast/slow* was considered the most representative scale for the A dimension in some other studies (Analysis I, Osgood, 1957; Tzeng, 1975). If *fast/slow* was the most representative scale of the A dimension rather than *active/passive*, at least for the current subject population, the results could be readily explained. *Active/passive* transferred to *strong/weak* because *active/passive* had a significant loading on the same factor as *strong/weak did*. Meanwhile *fast/slow* didn't transfer to *strong/weak* because it's a relatively pure scale of the A dimension, orthogonal to the P dimension of *strong/weak*. This idea was tested in the Experiment 3.

Experiment 3

Experiment 3 examined whether it was due to the ambiguous status of the *active/passive* and *fast/slow* scales that RP was found from *active/passive* to *strong/weak* and no RP from *fast/slow* to *strong/weak*. If *fast/slow* was an intermediate scale loaded on both P and A factors, some RP should be found when it's crossed with the *strong/weak* task. In contrast if *fast/slow* loaded only on the A factor, no cross-task transfer should be found according to the current hypothesis.

Fast/slow was used as the representing scale of the A dimension. It was shown in experiment 2 that there was no significant transfer from *fast/slow* to *strong/weak*, therefore only the *strong/weak* to *fast/slow* direction was tested here. There were 32 subjects in Experiment 3. They performed the *strong/weak* task at acquisition and both *strong/weak* and *fast/slow* tasks at tests.

Table 4 RP Effects from *Strong/weak* to *Fast/slow* (ms)

task (1-2)	new items	old items	priming effects	t-score
s/w-s/w	1017	865	152	7.27***
s/w-f/s	1083	1099	-16	-0.72

*** P<0.001

Results from this experiment were presented in Table 4. The same-task condition of *strong/weak* to *strong/weak* showed highly significant RP effect comparable to the effects in Experiment 1 and 2. Since highly significant RP effects in same-task conditions had been observed consistently across studies, and the main concern of the research involved relations between different scales, only cross-task conditions were tested in later experiments. No RP was found from *strong/weak* to *fast/slow*, in accordance with the hypothesis that *fast/slow* had significant loading only on the A factor. Subjects were faster in performing the *strong/weak* than *fast/slow* task, t_{30}=6.62, P<0.001.

Experiment 4

Experiment 4 was designed to complete the cross between *active/passive* and *fast/slow* and investigate the transfer pattern between scales with overlapping loadings on the same factors. *Active/passive* and *fast/slow* both loaded mainly on the A factor, according to the current hypothesis these two tasks should transfer to each other.

Since significant transfer had been found *fast/slow* to *active/passive* in Experiment 2, only the *active-passive* to *fast/slow* direction was tested in this experiment. Sixteen students participated in the study. Significant transfer was found. Table 5 integrated the result for *fast/slow* to *active/passive* condition in Experiment 2 with result from this study.

Table 5 RP Effects between *Active/passive* and *Fast/slow* (ms)

task (1-2)	new items	old items	priming effects	t-score
f/s-a/p	1026	985	41	2.05*
a/p-f/s	1092	999	93	4.64***

*** P<0.001 * P<0.05

Experiment 5

Experiment 5 was to study the RP pattern between tasks from the E and A dimensions. *Pleasant/unpleasant* and *fast/slow* were used as representative scales for the E and A dimensions, respectively. No transfer was predicted between these two tasks. Thirty-two students participated in this experiment.

No RP effect was observed in either cross-task condition. Results were reported in Table 6.

Table 6 RP Effects between *Pleasant/unpleasant* and *Fast/slow* (ms)

task (1-2)	new items	old items	priming effects	t-score
p/u-f/s	1080	1067	13	0.55
f/s-p/u	918	895	23	0.51

Experiment 6

Experiment 6 reinvestigated the RP pattern between an intermediate Scale and scales representative of its component dimensions. Some RP was predicted for the intermediate scale to both component dimension scales.

Young/old was selected as a judgment tapping both the E and A dimensions. Thirty-six subjects participated in this experiment. All subjects had the *young/old* judgment task at acquisition. There were 20 subjects in the *young/old-pleasant/unpleasant* group.

RP effect was found only in the *young/old* to *fast/slow* task condition and not in the *young/old* to *pleasant/unpleasant* condition (Table 7).

Table 7 RP Effects from *Young/old* to *Pleasant/unpleasant* and *Fast/slow* (ms)

task (1-2)	new items	old items	priming effects	t-score
y/o-p/u	879	883	-4	-0.41
y/o-f/s	1148	1082	66	2.94**

** P=0.01

Experiment 7

In Experiments 1, 5 and 6 no significant transfer was observed from any other judgment to the *pleasant/unpleasant* judgment task. For the semantic differential mediated memory space hypothesis to hold, within-dimensional transfer is as important as the null transfer between independent dimension judgment tasks. Experiment 7 further examined the within-dimensional transfer pattern of the E dimension.

Valuable/worthless was selected as the within-dimensional task related to *pleasant/unpleasant* on the E dimension. They both had high loadings exclusively on the E factor. Forty-four students participated in this experiment. There were 16 subjects in the *pleasant/unpleasant* to *valuable/worthless* and 28 in the *valuable/worthless* to *pleasant/unpleasant* condition. The greater N in the latter case was the result of testing additional subjects to enhance the power for detection of RP if it was present.

The transfer was asymmetrical between the two tasks, with significant RP from *pleasant/unpleasant* to *valuable/worthless* and non-significant in the other direction. Table 8 showed the results.

Table 8 RP Effects between *Pleasant/unpleasant and Valuable/worthless* (ms)

task (1-2)	new items	old items	priming effects	t-score
p/u-v/w	1172	1087	85	3.35**
v/w-p/u	957	922	35	1.86

** P<0.01

CHAPTER IV

DISCUSSION

Results from the above 7 experiments can be divided into two major categories, same-task transfer conditions and cross-task transfer conditions. Cross-task transfer conditions can be further divided into two groups – orthogonal-dimension task transfer and shared-dimension task transfer conditions. Data from all the experiments were rearranged according to this categorization, RP patterns shown in Figure 2 – 4. Error bars represented standard error of the means.

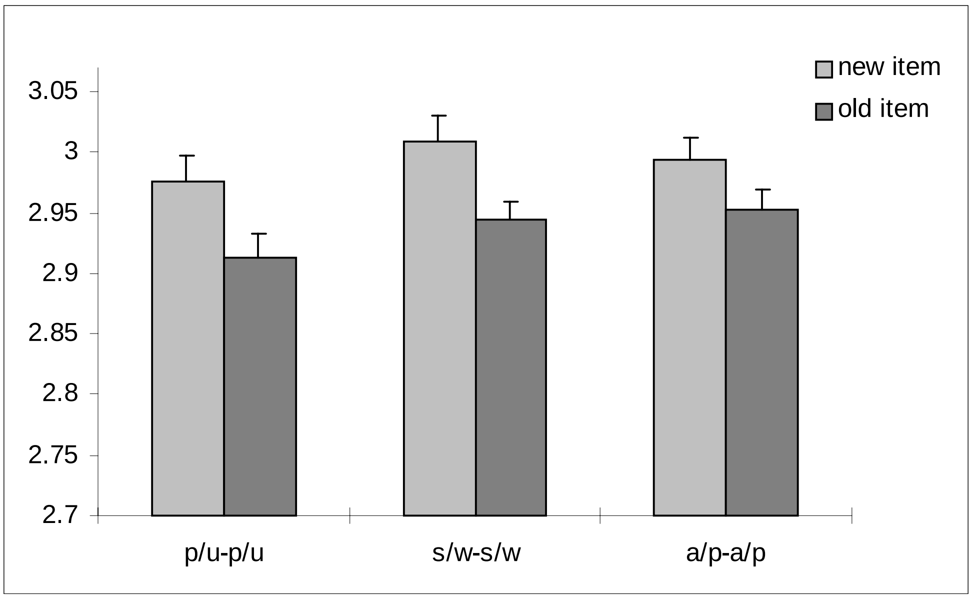

Figure 2 Priming in Same-Task Transfer Conditions

Maximum RP effects were found in same-task transfer conditions, ranging from 92 to 164 ms. RP effects in cross-task transfer conditions, when significant, ranged from 41 to 93 ms. This was compatible with results reported in Franks et al., 2000, where maximum RP was also found in same-task transfer conditions. This pattern was in accordance with TAP, which suggested that maximum transfer should be found when there was maximum overlap between test and acquisition events.

In support of the semantic differential mediated memory space hypothesis, no priming was observed in any of the orthogonal-dimension task conditions even though they involved processing on the same stimuli (Figure 3).

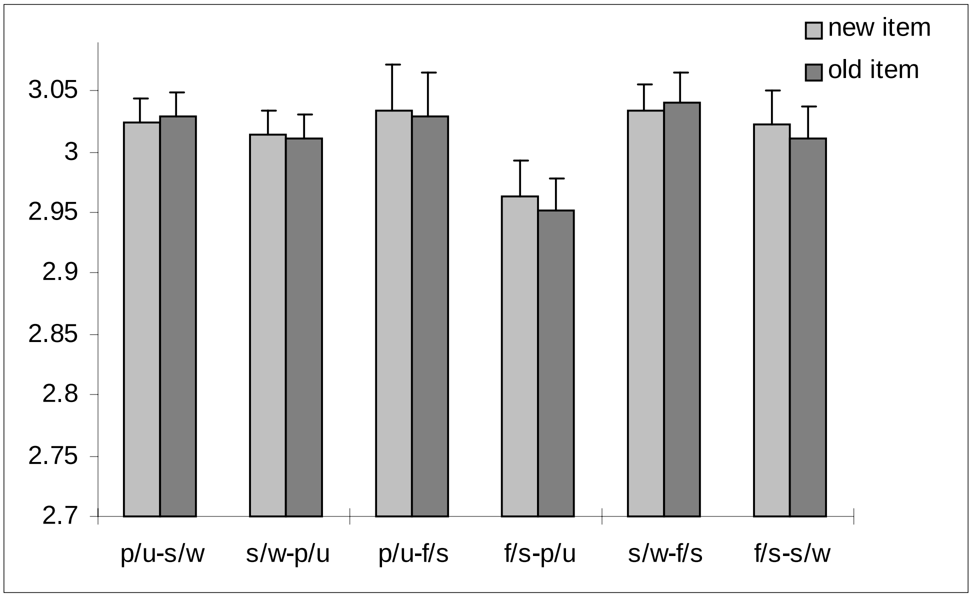

Figure 3 Priming in Cross-Task Transfer Conditions (Orthogonal-Dimension)

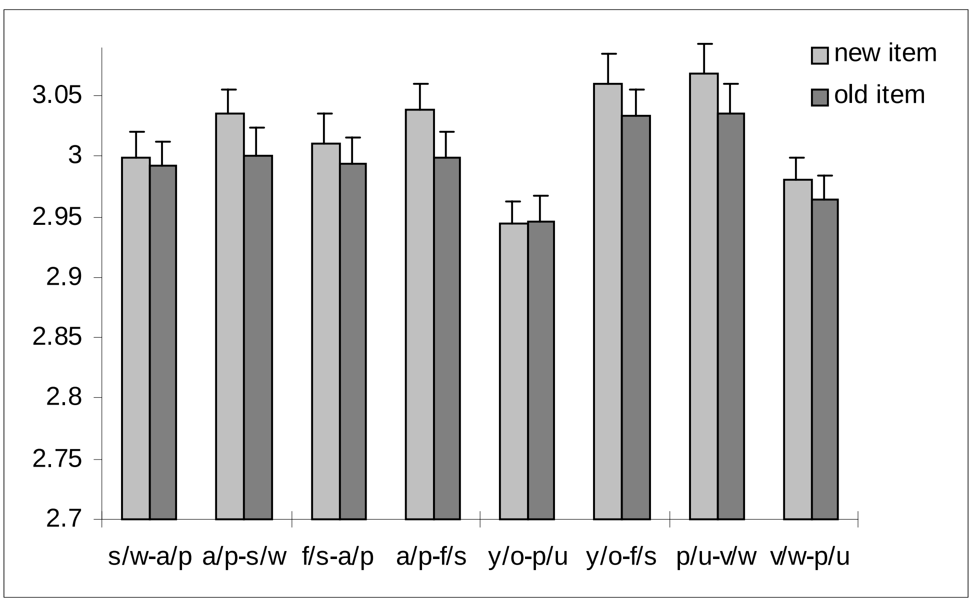

Figure 4 Priming in Cross-Task Transfer Conditions (Shared-Dimension)

For shared-dimension task conditions (Figure 4), although significant transfer was observed in many of them, the patterns were almost always asymmetrical. Significant RP was found from *active/passive* to *strong/weak* judgment task but not in the opposite direction. The transfer from *pleasant/unpleasant* to *valuable/worthless* was quite reliable with 16 subjects ($P<0.01$) while the transfer in the other direction didn't quite reach the significance level ($P=0.07$) with 28 subjects. Even when reliable RP effects were found in both directions, the pattern remained asymmetrical. The transfer from *fast/slow* to *active/passive* was much less than the transfer from *active/passive* to *fast/slow*, 41 vs. 93 ms, which happened to be the lowest and highest significant transfer in cross-task conditions. *Young/old* had equivalent loadings on the E and A factors, reliable transfer was found only from *young/old* to *fast/slow* and not in the *young/old* to *pleasant/unpleasant* condition.

The asymmetrical pattern in shared-dimension task conditions presented challenge to the original hypothesis. The original hypothesis is based on cross-correlations between judgment scales in the semantic space. It can’t be used to predict asymmetrical transfer pattern since correlations are nondirectional.

To accommodate the asymmetrical pattern the original hypothesis is further theoretically developed with the concept of “spread”, as described in detail in the following section, Mathematical Modeling.

As to the asymmetrical pattern from *young/old* to *fast/slow* and *young/old* to *pleasant/unpleasant*, one explanation may be that semantic dimensions differ in “density” of scaling representation. The E factor has been consistently found to account for more than twice the variance than either P or A factor across semantic differential studies (Bentler & LaVoie, 1972; Osgood et al., 1957; Tzeng, 1975; Tzeng & May, 1975; Wickens & Lindberg, 1975). Many scales have high loadings on the E factor while only a few scales have relatively high loadings on P or A factors. Also, typical E dimension scales have much higher loadings on the E factor than typical P or A dimension scales have on their respective factors. The E dimension may in some sense be more compact or denser than the P or A dimension, and require more extensive overlap, as indicated by higher loadings on E factor, for E dimension scales to show the same amount of transfer as scales of less dense P or A dimension. The idea is assessed in mathematical modeling by weighting the semantic dimensions.

CHAPTER V

MATHEMATICAL MODELING

Data from 14 cross-task transfer conditions were modeled with two kinds of models, the Distance Model and Distance-Spread Model. Data from same-task conditions were not included in modeling because processes underlying same- and cross-task transfer conditions might be different according to the instance theory (Logan, 1988, 1990). Instance theory was first developed as a theory of automatization and later applied to RP as well. Instances are representations of individual exposure to a specific stimulus. Subjects' performance on tasks is the result of a race between memory and algorithm. Subjects respond according to whichever wins the race. The more instances a subject has in his memory, the more likely for him to respond from memory rather than computing the response. In the present case, in accordance with TAP, an instance should involve not only the specific stimulus but also the kind of processing that's performed on it. In same-task conditions when subjects first performed the task on a word stimulus, an instance of "word-processing" was laid down in the memory. When they were to perform the same task on the same word stimulus again they might simply retrieve the response from memory instead of computing the response from some algorithm. If concepts (word stimuli) consisted of instances, the algorithm could be counting positive vs. negative instances with regard to the property of the scale (Nosofsky & Palmeri, 1997). The algorithm is elaborated in more detail in the Distance-Spread Model section. Contrary to this, in cross-task transfer conditions no "word-processing" instance had been laid down for the second judgment. Subjects had to perform the task by algorithm. It is cross-task transfer conditions that presented difficulty for the original hypothesis, therefore only cross-task conditions were modeled.

Priming effects in direct RTs were used in modeling. All modeling was done with Solver, Microsoft Excel 97. The criterion was to maximize R^2 as calculated in *v.*1.

$$R^2 = 1 - \sum_{k=1}^{14} (RP_k - RP_{k.pred.})^2 / \sum_{k=1}^{14} RP_k{}^2 \qquad (1)$$

RP_k was the RP effect in condition k in ms, $RP_{k.pred.}$ was the predicted effect for condition k by the model.

Distance Model, Unweighted and Weighted

The original hypothesis is essentially a distance model of meaning priming. When the same task was used in both acquisition and test, the distance between tasks was zero. When scales shared processing on the same semantic dimension(s), they were closer to each other in the semantic space than when they fell on orthogonal dimensions. When scales representing orthogonal semantic dimensions were crossed, the distance between scales was maximized. Accordingly, maximum RP was predicted for scales closest to each other, less but some RP for scales which were close to each other, and no RP for scales maximally away from each other. The Distance Model inherently predicts symmetrical priming for both cross-task directions.

In modeling the experimental results, RP was assumed to be a monotonically increasing function of distance. It was modeled with the exponential function (Nosofsky & Palmeri, 1997).

$$RP_i = RP_j = s \cdot e^{D_{ij}} \tag{2}$$

$$D_{ij} = \sqrt{(l_{i.e} - l_{j.e})^2 + (l_{i.p} - l_{j.p})^2 + (l_{i.a} - l_{j.a})^2} \tag{3}$$

D_{ij} was the distance between scale i and scale j. $L_{i.e}$, $l_{i.p}$ and $l_{i.a}$ were scale i's loadings on the E, P and A factors. Likewise for scale j. D_{ij} was calculated directly from these loadings. There was only one free parameter in this model, s, the scalar.

Maximum R^2 was found when s=43.25, R^2=0.73. Predicted RP effects were presented in Figure 5 together with the original data. The predicted effects showed the same increasing trend from orthogonal to share-dimension transfer conditions as data but they failed to catch the asymmetries, including *young/old* to *pleasant/unpleasant* and *young/old* to *fast/slow*.

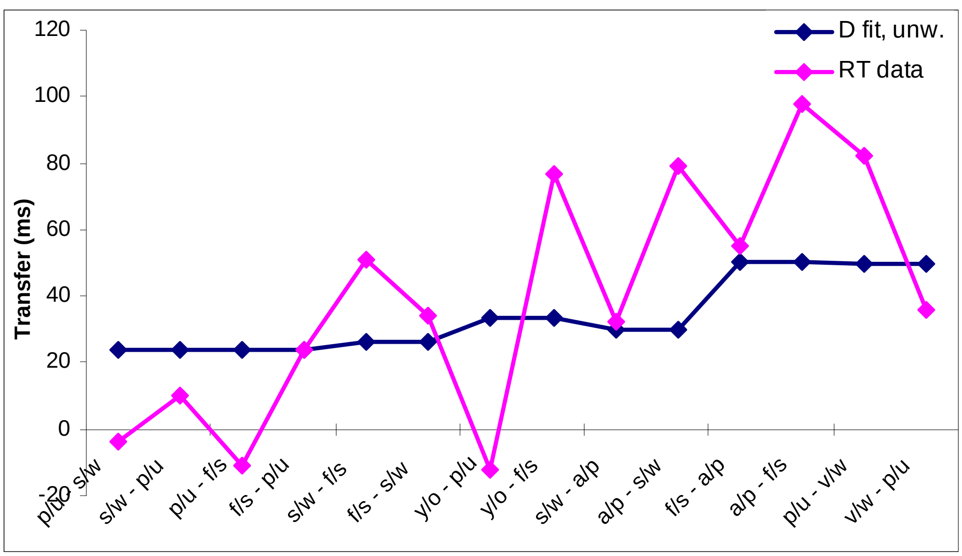

Figure 5 Distance Model Fit, Unweighted

The idea of a "denser" E dimension is proposed in order to explain the asymmetrical effects between *young/old* to *pleasant/unpleasant* and *young/old* to *fast/slow* conditions. Weighted dimensions have been employed by some researchers to explain asymmetrical effects involving similarity judgments (Krumhansl, 1978). Density of different semantic dimensions was modeled here by weighting them according to the proportion of total accountable variance the corresponding factor accounted for in *Analysis I* (Osgood et al., 1957). For the weighted Distance Model,

$$RP_i = RP_j = s \cdot e^{D_{ij.w}} \tag{4}$$

$$D_{ij.w} = \sqrt{[w_e(l_{i.e} - l_{j.e})]^2 + [w_p(l_{i.p} - l_{j.p})]^2 + [w_a(l_{i.a} - l_{j.a})]^2} \tag{5}$$

Maximum R^2 was found when s=59.63, R^2=0.80, accounting for slightly more variance than the unweighted model. Results were presented in Figure 6. The weighted Distance Model correctly predicted the direction of asymmetry as seen in the transfer from *young/old* to *fast/slow* and *young/old* to *pleasant/unpleasant* data, but it failed to capture the magnitude of difference in these two conditions.

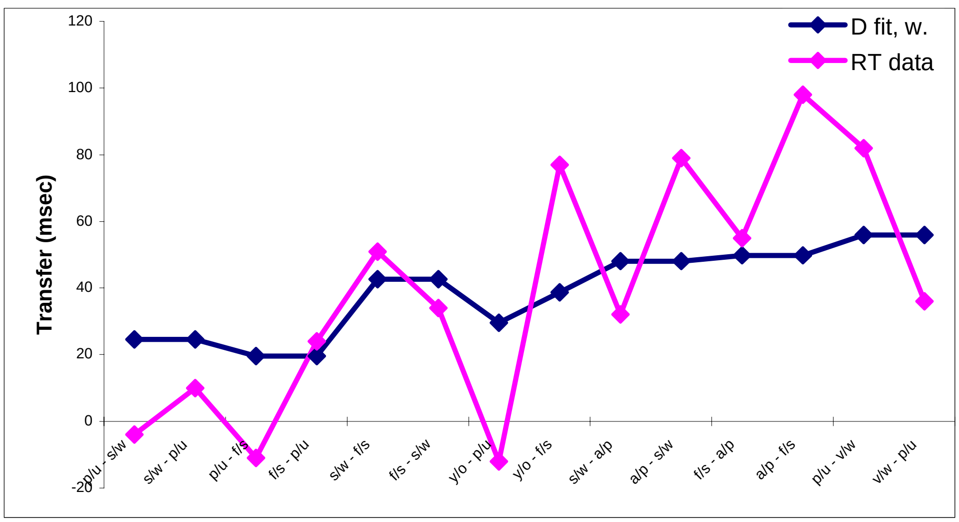

Figure 6 Distance Model Fit, Weighted

Overall Distance Models upon which the original hypothesis is dependent failed to capture what seemed to be an important property of RP pattern in cross-task conditions, the asymmetry of transfer from task A to task B and task B to task A. One way to implement the original distance hypothesis was explored with the Distance-Spread Model.

Distance-Spread Model, Weighted

It was assumed that concepts, including both words and judgment scales, consisted of instances and subjects used the counting algorithm proposed earlier to perform the judgment task (Nosofsky & Palmeri, 1997). When they judged a word stimulus with regard to the property of the judgment scale, a subset of instances that's appropriate to both the word stimulus and judgment scale would be retrieved, as illustrated by the overlapping part *P* in Figure 7. Note that only a subset of the overlapping instances need to be retrieved instead of all the instances that fell within overlap *P*. Subject could make response soon as the number of instances positive or negative of the scale property exceeded the other by a certain amount. The faster the subject retrieved the instances, the faster the response time could be.

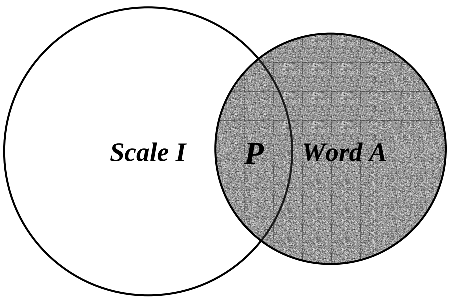

Figure 7 Independent Judgment

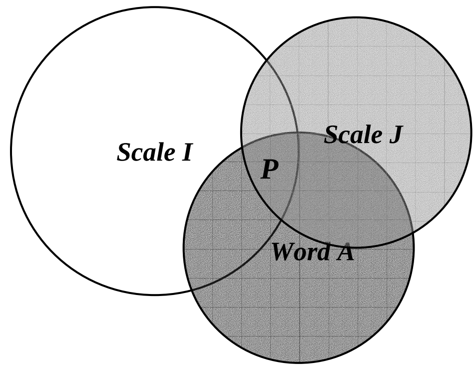

Figure 8 Priming of Judgments

In the above experiments when a subject made a judgment about a word, a subset of the instances was retrieved. Instances recently retrieved would likely be easier to retrieve than those that were not recently retrieved. Later when the subject was required to make another judgment on the same word, the probability that the same instances retrieved during acquisition would be retrieved again at test should increase as a function of the overlapping instances of the two judgment scales and the word, shown as part *P* in Figure 8. Because instances retrieved earlier were more easily retrieved, savings in RT, i.e. transfer would happen. The amount of transfer would be determined by the overlapping part *P*.

The influence of words on RP in these experiments was carefully controlled, as described in Methods. In this modeling it was assumed that word stimuli didn't bias towards either judgment task. The instance set of words was thus dropped from the model. Priming between judgment task was then determined simply by the overlap between judgment scales, shown as part *Q* in Figure 9a and Figure 9b. The representation was further simplified into center of circles and overlapping radius in Figure 9b for computational convenience. Distance between centers was the distance between scales, the same as in the original Distance Models. "Spread" was introduced to describe the variability of concepts, depicted as radius in Figure 9b.

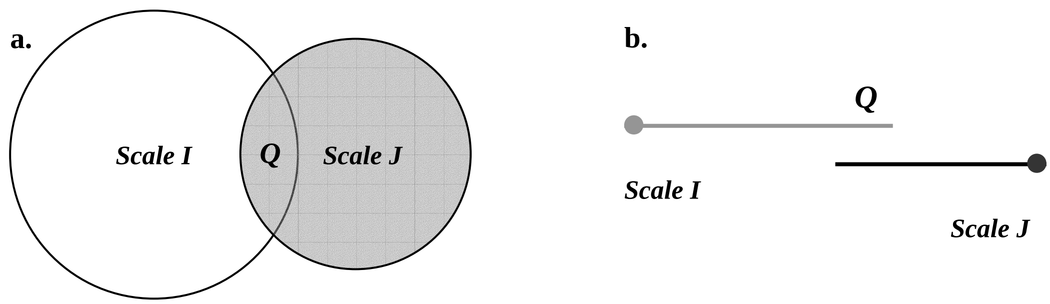

Figure 9 Priming of Judgments, Simplification

When considered as sets of instances, concepts should differ in the number of instances they have and also differ in the similarity of instances within each concept. If a concept had fewer instances or its instances were more similar to each other than another concept, it was assumed to have a smaller spread, like *Scale J* in Figure 9. The overlap *Q* took a bigger proportion in *Scale J* than *Scale I*, which means that the probability that instances retrieved during acquisition would be retrieved again was higher from *Scale I* to *Scale J* than from *Scale J* to *Scale I*. There would be asymmetry in the transfer pattern between this pair of tasks. Priming effect would be determined not only by the distance between scales, but also the spread of scales.

In the Distance-Spread Model, *RP* from *Scale I* to *Scale J* was a function of the proportion of overlap *Q* to the spread of *Scale J*; vice versa for *RP* in the reverse direction. The spread of a scale was modeled as inversely related to its communality (h^2) with the E-P-A factors. The logic behind was that the more variance that was explained by the less factors, the more compact the concept would be. For example, *pleasant/unpleasant* loaded highly and almost exclusively on the E factor. It had a relatively high h^2, 0.77. The loadings of *young/old* weren't necessarily low but spread out on all the factors. It had an h^2 of 0.23. *Wet/dry* loaded low on all the factors, h^2=0.03, indicating that its meaning was so spread out that it need to be explained by additional factors besides E, P and A. The inverse of h^2 was thus taken as the description for the spread of a scale.

$$r_i = a \cdot (1/h_i^{\,2}) \tag{6}$$

$$P_j = [(r_i + r_j - D_{ij.w})/r_j]^2 \qquad (Max(r_i, r_j) < D_{ij.w} < r_i + r_j) \tag{7}$$

$$RP_{i.j} = \begin{cases} s \cdot e^{P_j} & (r_i + r_j > D_{ij.w}) \\ 0 & (r_i + r_j \le D_{ij.w}) \end{cases} \tag{8}$$

$RP_{i.j}$ was the priming from *Scale I* to *Scale J*; for the condition in which two scales didn't overlap at all ($r_i + r_j \le D_{ij.w}$), *RP*'s were simply set to zero instead of allowing for negative priming (inhibition). P_j was proportion of *Q* to the spread of *Scale J* squared. It was squared in order to increase the difference between conditions; r_i and r_j were spread of *Scale I* and *J*, respectively. Another scalar *a* was used to bring r_i's into the range of $D_{ij.w}$'s. Weighted distances were used for they showed better fitting than unweighted distances in the Distance Models.

For the special condition in which one set of instances was completely imbedded in the other ($D_{ij.w}$<Max(r_i, r_j)), if $r_i < r_j$,

$$P_j = (r_i / r_j)^2 \tag{9}$$

or if $r_i > r_j$,

$$P_j = 1 \tag{10}$$

There were two free parameters and 14 data points in this model. When s=27.35 and a=0.06, maximum R^2 was found to be 0.89. The model fit was shown in Figure 10.

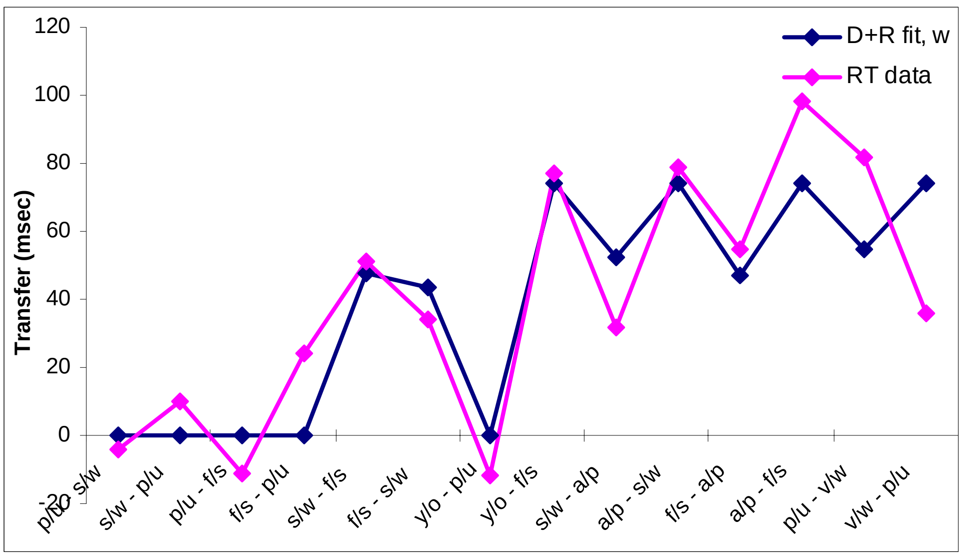

Figure 10 Distance-Spread Model Fit

The Distance-Spread model correctly predicted the direction of all asymmetries except in the *pleasant/unpleasant* and *valuable/worthless* cross conditions. It captured the magnitudes nicely as well. The Distance-Spread Model produced much better fit to the experimental data than the original distance only models.

CHAPTER VI

GENERAL DISCUSSION

In the current study the hypothesis that priming between meaning-judgment tasks is mediated by overlapping semantic processes of judgment scales was tested. The original hypothesis is essentially a distance model of meaning priming. In accordance with the TAP principle, maximum RP was predicted when judgment scales overlap maximally with each other (the same-task conditions); some but less than maximum RP was predicted when scales shared processes on the same semantic dimension(s); little or no RP was predicted when judgment scales fell on orthogonal dimensions, i.e. when scales were maximally away from each other. Transfer was assumed to be inversely related to the distance between scale.

Consistent with the hypothesis, maximum RP was found in same-task conditions, *pleasant/unpleasant* to *pleasant/unpleasant*, *strong/weak* to *strong/weak* and *active/passive* to *active/passive*. When tasks mainly required processing on the orthogonal semantic dimensions of E, P or A, *pleasant/unpleasant* and *strong/weak*, *pleasant/unpleasant* and *fast/slow*, *strong/weak* and *fast/slow*, no RP was found even with the word stimuli repeating. The asymmetrical RP pattern found when tasks shared some processing on the same dimension(s), with more transfer from *active/passive* to *strong/weak*, *active/passive* to *fast/slow*, *pleasant/unpleasant* to *valuable/worthless* and less or no transfer in the reverse direction, however, presented challenge for the original distance hypothesis. Even though the priming asymmetry from *young/old* to *pleasant/unpleasant* and *young/old* to *fast/slow* could be partially accounted for by weighting the dimensions, as demonstrated in Mathematical Modeling, the distance model couldn't explain asymmetries in the experimental data since the distance between pairs of scales was nondirectional.

Another variable, the spread of scales was introduced to implement the original distance only model. Spread was a description of the variability between concepts when they were considered sets of instances. Spread was proposed to be related to RP in such a fashion: the smaller the spread, the more likely for a scale to get transfer from other scales and less likely to prime the processing of other scales. The Distance-Spread Model captured the direction of asymmetries in the experimental data amazingly well, the only exception being the *pleasant/unpleasant* and *valuable/worthless* cross conditions. It also predicted the magnitude of RP effects, showing much better fit to the experimental data than distance only models.

The semantic differential was shown to be a very useful guiding heuristic in choosing scales. Nevertheless its explanation power for RP patterns is limited. It is based on correlational study and intrinsically nondirectional. It has more utility in understanding and providing an estimate for the distance, or dissimilarity (Ashby & Perrin, 1988; Krumhansl, 1978) between scales than variability. The variability between concepts can come from at least two sources other than the semantic space – the number of instances in each concept and how similar those instances are to each other within a concept. It will be of interest to develop ways to model these variables and investigate their respective influence on RP patterns instead of using the gross simulation of spread. For example, model the number of instances in a concept with word frequency and investigate the influence of word frequency on RP effects. It may be the way to understand the asymmetry between *pleasant/unpleasant* and *valuable/worthless* given the experimental results replicate.

Implicit memory tests has been shown to be greatly affected by the perceptual property of the stimuli, even font type and letter case (Roediger & McDermott, 1993; Shimamura & Squire, 1984). In the present study the stimuli remained exactly the same. Whether RP occurred or not depended solely upon the kind of semantic processing performed on the stimuli. Previous work (Franks et al., 2000) and the present study both demonstrated that the implicit memory was highly sensitive to specific processes and the TAP principle had utility in differentiating type of semantic processes and process overlap. The use of TAP went beyond the application of a general perceptual or conceptual sense (Blaxton, 1989; Roediger & McDermott, 1993). The cross transfer experimental design developed within the TAP framework should retain its guiding role in empirically mapping out the structure of the implicit memory space.

Appendix A

Semantic Scales and Factors

	I	II	III	IV	h^2
1 active-passive	0.14	0.04	0.59	-0.02	0.37
2 fast-slow	0.01	0.00	0.70	-0.12	0.50
3 pleasant-unpleasant	0.82	-0.05	0.28	-0.12	0.77
4 strong-weak	0.19	0.62	0.20	-0.03	0.46
5 valuable-worthless	0.79	0.04	0.13	0.00	0.64
6 young-old	0.31	-0.30	0.32	0.01	0.29
		……			
% Total Variance	33.78	7.62	6.24	1.52	0.4916
% of Common Variance	68.55	15.46	12.66	3.08	0.9975

- The Measurement of Meaning, Osgood et al., 1957

Appendix A was adapted from Rotated Factor Loadings – Analysis I, Osgood et al. (1957). In studying the semantic space, Osgood et al. had subjects rate 20 words on a 7-point scale with regard to semantic scales such as "*active-passive*". The ratings for different semantic scales were correlated with each other, resulting in a cross-correlation matrix. Factor analysis was performed on this correlation matrix. Factors I – III was suggested to represent the Evaluation, Potency and Activity dimensions of the semantic space.

Appendix B

Word Stimuli for Experiment 5, *Pleasant/unpleasant* and *Fast/slow*

pleasant-fast			pleasant-slow			unpleasant-fast			unpleasant-slow		
	E	A		E	A		E	A		E	A
answer	0.72	0.47	beauty	2.21	-1.23	action	-0.37	1.43	connectioı	-0.11	-0.79
baby	1.39	1.42	book	1.07	-0.56	attention	-0.19	0.17	cost	-1.00	-0.40
bird	1.07	2.05	bread	1.14	-1.75	battle	-2.93	1.82	difference	-0.10	-0.28
boat	1.08	0.67	bridge	0.96	-1.34	blood	-1.11	1.33	difficulty	-1.97	-0.68
college	1.07	1.29	church	2.01	-1.05	chief	-0.62	1.31	door	-0.42	-1.57
discovery	0.90	1.47	cloud	0.19	-0.41	city	-0.75	1.08	doubt	-1.19	-0.81
doctor	0.88	0.73	color	1.09	-0.35	court	-1.31	0.85	end	-0.83	-1.93
dollar	0.30	0.59	egg	1.12	-3.13	cry	-1.30	0.19	failure	-2.96	-1.58
eye	0.67	0.68	flower	1.67	-0.30	custom	-0.05	0.60	fear	-2.68	-0.16
football	0.66	1.75	milk	1.38	-0.96	danger	-2.75	1.49	ground	-0.05	-0.78
game	0.81	1.51	moon	0.83	-1.71	empire	-0.54	1.03	heat	-0.52	-0.12
health	1.29	0.70	picture	1.41	-1.79	factory	-0.93	0.44	left	-0.62	-1.18
home	1.48	0.84	road	0.48	-1.53	force	-1.00	1.20	limit	-0.36	-0.66
hospital	0.96	0.65	sand	0.38	-1.24	judge	-0.65	0.63	loss	-1.72	-1.32
laugh	0.73	1.93	school	0.66	-0.09	mouth	-0.65	0.68	middle	-1.14	-1.63
life	0.65	0.86	silver	1.23	-0.85	movemen	-0.10	0.82	piece	-0.41	-0.91
light	0.40	0.58	story	0.83	-0.12	politics	-1.38	1.11	plan	-0.54	-0.52
sailor	0.67	2.43	tree	1.23	-0.65	trouble	-2.75	0.86	problem	-1.60	-0.43
town	0.70	0.41	wall	0.24	-1.99	wind	-0.83	0.69	situation	-1.40	-0.15
victory	1.06	1.35	wish	1.14	-0.75	winter	-2.21	1.06	stone	-0.50	-2.87
mean	0.91	1.12		1.06	-1.09		-0.95	0.94		-1.01	-0.94

Numbers in this table are Eigenvalues of words on semantic factors relevant to the judgment scales (Heise, 1965).

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