of component execution, it would appear that the process model presented in Figure 6.2a best, defined task performance on Semidegenerate (A:A::B:B) forced choice geometric analogy items.

Semidegenerate (A:B::A:B) Geometric Analogy Subjective Task Strategy Types

It wil be recalled from the section Semidegenerate Forced Choice Geometric Analogy (Format A:B::A:B) Subjective Task Strategy Types in Chapter 5, that in terms of performance components adopted and order of component execution, two dominant subjective task strategy types were identified from subjects post hoc introspective reports relating to the 1 element - 1 transformation Semidegenerate (A:B::A:B) geometric analogy example.

Twenty-nine subjects (48%) reported employing the first of these dominant strategy types. A schematic flow chart of this strategy type is presented in Figure 6.3a.

Subjects employing this dominant strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first two analogy terms. The subjects then encode the third analogy term and, following this, map the relation between the first and third terms. The two answer options are then encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

Three variations of this strategy type were identified. These variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations,

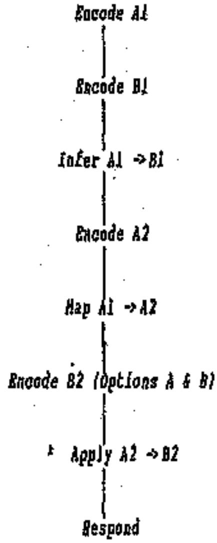

Figure 6.3 (a) Schematic flow chart of the first dominant subjective task strategy type applicable to Semidegenerate (A:B::A:B) item solution.

Variations of this process

- *As applicable to 1 element - 1 transformation Semidegenerate (A:B::A:B) item solution.*

(1) *Self-terminating, irrespective of which answer option was correct - employed by thirteen subjects (22%).*

(2) *Exhaustive, irrespective of which answer option was correct - employed by four subjects (7%).*

(3) *Self-terminating if first answer option correct, and exhaustive if second answer option correct - employed by twelve subjects (20%).*

- *As applicable to 3 element - 3 transformation Semidegenerate (A:B::A:B) item solution.*

(1) *Exhaustive, irrespective of which answer option was correct - employed by eleven subjects (18%).*

(2) *Self-terminating if first answer option correct, and exhaustive is second answer option correct - employed by twelve subjects (20%).*

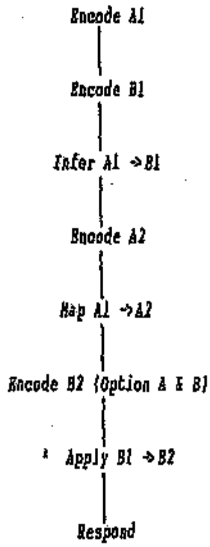

Figure 6.3 (b) Schematic flow chart of the second dominant subjective task strategy type applicable to Semidegenerate (A:B::A:B) item solution.

* *Variations of this process*

- *As applicable to 1 element - 1 transformation Semidegenerate (A:B::A:B) item solution.*

(1) *Self-terminating, irrespective of which answer option was correct - employed by nine subjects (15%).*

(2) *Exhaustive, irrespective of which answer option was correct - employed by twelve subjects (20%).*

(3) *Self-terminating if first answer option correct, and exhaustive if second option correct - employed by ten subjects (17%).*

- *As applicable to 3 element - 3 transformation Semidegenerate (A:B::A:B) item solution.*

(1) *Exhaustive, irrespective of which answer option as correct - employed by eighteen subjects (30%).*

(2) *Self-terminating if first answer option correct, and exhaustive if second answer option correct - employed by nineteen subjects (32%).*

employed by thirteen subjects (22%), involved a self-terminating application process, irrespective of which answer option was the correct one. The second variation, employed by four subjects (7%). involved an exhaustive application process, irrespective of which answer option was the correct one. The third variation employed by twelve subjects (20%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was correct.

Thirty-one subjects (52%) reported employing the second dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.3b.

Subjects employing [illegible] t strategy type begin analogy solution b[illegible] st analogy term, and then the second analogy [illegible] infer the relation between the first two [illegible] subjects then encode the third analogy term [illegible] this map the relation between the first [illegible] terms. The two answer options are then encoded. [illegible] ng encoded the two answer options, subjects attempt to apply from the second term to each answer option in order to identify the answer option identical to the second term. Subjects would then respond either "A" or "B", thereby completing the analogy problem.

Three variations of this dominant strategy type were identified. Again, these variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by nine subjects (15%), involved a self-terminating application process irrespective of which answer option was correct. The second variation, employed by twelve subjects (20%), involved an exhaustive application process, irrespective of which answer option was the correct one. The third variation, employed by ten subjects (17%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was the correct one.

It was noted previously in the section Semidegenerate Forced Choice Geometric Analogy (Format A:B::A:B) Subjective Task Strategy Types in Chapter 5, that in terms of performance components adopted and order f component execution, two dominant subjective task strategy types, identical to those identified for the 1 element - 1 transformation Semidegenerate (A:B::A:B) geometric analogy example, were identified from subjects' post hoc introspective reports relating to the 3 element - 3 transformation Semidegenerate (A:B::A:B) geometric analogy example.

Twenty-three subjects (38%) reported employing the first of these dominant strategy types. See Figure 6.3a earlier in this section for the schematic flow chart of this strategy type. Since this strategy type has been described previously, in the discussion pertaining to the 1 element - 1 transformation Semidegenerate (A:B::A:B) geometric analogy example, it will not be described again. It is, however, important to note that two variations of this strategy type were identified. These variations were apparently attributable to subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by eleven subjects (18%), involved an exhaustive application process, irrespective of which answer option was the correct one. The second variation, employed by twelve subjects (20%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was correct.

Thirty-seven subjects (62%) reported employing the second dominant strategy type. See Figure 6.3b earlier in this section for a schematic flow chart of this strategy type. Since this strategy type has been discussed previously, in the discussion pertaining to the 1 element - 1 transformation Semidegenerate (A:B::A:B) geometric analogy example, it will not be described again. It is, however, important to note that two variations of this strategy type were identified. These variations were apparently attributable to subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by eighteen subjects (30%), involved an exhaustive application process, irrespective of which answer option was the correct one. The second variation, employed by nineteen subjects (32%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was correct.

The preceding discussion of subjects post hoc introspective reports relating to the solution of both 1 element - 1 transformation and 3 element - 3 transformation Semidegenerate (A:B::A:B) forced choice geometric analogy items reveals a number of issues relevant to the present research. Firstly, in terms of performance components adopted and order of component execution, subjective task strategy reports suggest the dominance of two strategy types for both 1 element - 1 transformation and 3 element - 3 transformation Semidegenerate (A:B::A:B) items (see Figures 6.3a and 6.3b earlier in this section for schematic flow charts of these strategy types). The major difference between these strategy types being that the strategy type presented in Figure 6.3a involves application from the third term to each answer option, whereas the strategy type presented in Figure 6.3b involves application from the second term to each answer option. Secondly, and possibly more significant to the present study, is that the two dominant subjective task strategy types identified from subjects' post hoc introspective reports relating to 3 element - 3 transformation Semidegenerate (A:B::A:B) items were identical to those reported for the solution of 1 element - 1 transformation Semidegenerate (A:B::A:B) items. Thus, it would appear that despite the increase in both the number of elements per analogy term, as well as the number of transformations between analogy terms, the identical two strategy types dominate. This would suggest that, on the basis of subjective strategy reports, for Semidegenerate (A:B::A:B) forced choice geometric analogy items, increases in item complexity fail to elicit meaningful strategic variations on the part of subjects in order to overcome increases in mental workload and maintain high standards of task performance. Thirdly, on the basis of subjective task strategy reports, variations of the dominant strategy types reported for both 1 element - 1 transformation and 3 element - 3 transformation Semidegenerate (A:B::A:B) item solution were identified. As noted earlier in this section these variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. Three variations of both dominant strategy types relating to 1 element - 1 transformation Semidegenerate (A:B::A:B) item solution were identified. These variations were discussed previously in this section

Two variations of both dominant strategy types pertaining to 3 element - 3 transformation Semidegenerate (A:B::A:B) item solution were identified. Again, these variations were discussed previously in this section. It is, however, important to note that subjects post hoc introspective reports relating to both 1 element - 1 transformation and 3 element - 3 transformation Semidegenerate (A:B::A:B) item solution revealed that order of answer options, i.e., which answer option was correct (A or B) was a determining factor of the type of application process employed. Where the first answer option was correct, subjects employing this strategy type variation would employ a self-terminating application process and where the second answer option was correct, these subjects would employ an exhaustive application process. This pattern was found to be more prominent in the subjective task strategy reports relating to the solution of 3 element - 3 transformation Semidegenerate (A:B::A:B) items than those relating to the solution of 1 element - 1 transformation Semidegenerate (A:B::A:B) items.

Therefore, based on subjects post hoc introspective reports regarding performance components adopted and order of component execution, it would appear that the process models presented in Figure 6.3a and 6.3b best define task performance on Semidegenerate (A:B::A:B) forced choice geometric analogy items.

Nondegenerate Geometric Analogy Subjective Task Strategy Types

It will be recalled from the section Nondegenerate Forced Choice Geometric Analogy Subjective Task Strategy Types in Chapter 5, that in terms of performance components adopted and order of component execution, four dominant subjective task strategy types were identified from subjects' post hoc introspective reports relating to the 1 element - 1 transformation Nondegenerate geometric analogy example.

Thirty-seven subjects (61%) reported employing the first of these dominant strategy types. A schematic flow chart of this strategy type is presented in Figure 6.4a.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second analogy terms The subjects then encode the third analogy term. Following this, the two answer options were encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

Three variations of this strategy type were identified. These variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by twelve subjects (20%), involved a self-terminating application process, irrespective of which answer option was the correct one. The second variation, employed by seventeen subjects (28%), involved an exhaustive application process, irrespective of which answer option was the correct one. The third variation, employed by eight subjects (13%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was correct.

Eight subjects (14%) reported employing the second dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.4b.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second analogy terms. The subjects then encode the third analogy term and, following this, map the relation between the third and second terms. The two answer options are then encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

Two variations of this strategy type were identified. These variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by four subjects (7%), involved a self-terminating application process; irrespective of which answer option was correct. The second variation, employed by four subjects (7%), involved an exhaustive application process, irrespective of which answer option was correct.

Twelve subjects (20%) reported employing the third dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.4c.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second terms. The subjects then encode the third analogy term and, following this, map the relation between the third and second terms. The two answer options are then encoded. Subjects then attempt to apply from the second term to each answer option in order to identify the answer option whose elements have undergone transformations identical to those having taken place between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

Three variations of this strategy type were identified. These variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by two subjects (3%), involved a self-terminating application process, irrespective of which answer option was correct. The second variation employed by eight subjects (13%), involved an exhaustive application process, irrespective of which answer option was correct. The third variation, employed by two subjects (3%), involved a self-terminating application process if the first answer option was correct, and an exhaustive application process if the second answer option was correct.

Three subjects (5%) reported employing the fourth dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.4d.

Subjects employing this analogy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and the second analogy terms. The subjects then encode the third analogy term and, following this, map the relation between the first and third terms. The two answer options are then encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

Two variations of this strategy type were identified. These variations apparently arose as a result of subjects employing either a self-terminating or exhaustive application process. The first of these variations, employed by one subject (2%), involved a self-terminating application process, irrespective of which answer option was correct. The second variation, employed by two subjects (3%), involved an exhaustive application process, irrespective of which answer option was correct.

It was noted previously in the section Nondegenerate Forced Choice Geometric Analogy Subjective Task Strategy Types in Chapter 5, that in terms of performance components adopted, order of component execution, nature of inference, mapping and application procedures (i.e.,

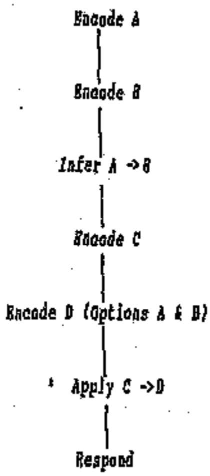

Figure 6.4 (a) Schematic flow chart of the first dominant subjective task strategy type applicable to 1 element - 1 transformation Nondegenerate item solution.

* *Variations of this process*

(1) Self-terminating, irrespective of which answer option was correct - employed [illegible] a subjects (20%).

(2) Exhaustive, irrespective of which answer options was correct - employed by seventeen subjects (28%).

(3) Self-terminating if first answer option correct, and exhaustive if second answer option correct - employed by eight subjects (13%).

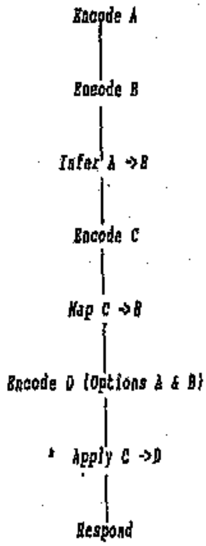

Figure 6.4(b) Schematic flow chart of the second dominant subjective task strategy type applicable to 1 element - 1 transformation Nondegenerate item solution.

* *<u>Variations of this process</u>*

(1) *Self-terminating, irrespective of which answer option was correct - employed by four subjects (7%).*

(2) *Exhaustive, irrespective of which answer option was correct - employed by four subjects (7%).*

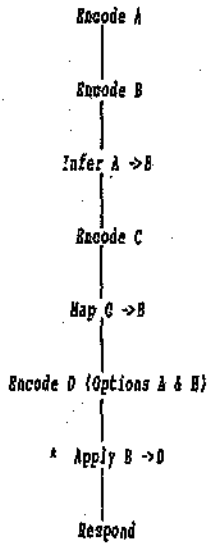

Figure 6.4 (c) Schematic flow chart of the third dominant subjective task strategy type applicable to 1 element - 1 transformation Nondegenerate item solution.

Variations of this process

(1) Self-terminating, irrespective of which answer options was correct - employed by two subject (3%).

(2) Exhaustive, irrespective of which answer option was correct - employed by eight subject (13%).

(3) Self-terminating if first answer option correct, and exhaustive if second answer option correct - employed by two subjects (3%).

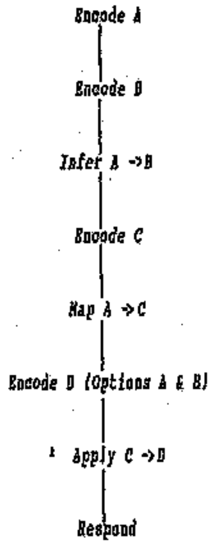

Figure 6.4 (d) Schematic flow chart of the fourth dominant subjective task, strategy type applicable to 1 element - 1 transformation Nondegenerate item solution.

* *Variations of this process*

(1) Self-terminating, irrespective of which answer option was correct - employed by one subject (2%).

(2) Exhaustive, irrespective of which answer option was correct - employed by two subjects (3%).

self-terminating or exhaustive), and mode of option scanning (i.e., sequential or alternate), four dominant subjective task strategy types were identified from subjects post hoc introspective reports relating to the 3 element - 3 transformation Nondegenerate example.

Twenty-two subjects (37%) reported employ' ,g the first of these dominant strategy types. A schematic flow chart of this strategy type is presented in Figure 6.5a.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second terms. The subjects then encode the third analogy term. Following this, the two answer options are encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

It is important to note that in t' is dominant strategy type, both the inference and application procedures are self-terminating and, furthermore, the mode of option scanning is alternate. No variations of this strategy type were identified.

Eleven subjects (18%) reported employing the second dominant strategy ty' e. A schematic flow chart of the strategy type is presented in Figure 6.5b.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second terms. The subjects then encode the third analogy term and, following this, map the relation between the third and second terms. The two answer options are then encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

It is important to note that in this dominant strategy type, inference, mapping and application are self-terminating processes. Furthermore, the mode of option scanning is alternate No variations of this strategy type were identified.

Twenty-three subjects (38%) reported employing the third dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.5c.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. The subjects then encode the third analogy term and, following this, map the relation between the third and second terms. The two answer options are then encoded. Subjects then attempt to apply from the second term to each answer option in order to identify the answer option whose elements have undergone transformations identical to those having taken place between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

It is important to note that in this dominant strategy type, inference, mapping and application are self-terminating processes. Furthermore, the mode of option scanning is alternate. No variations of this strategy type were identified.

Four subjects (7%) reported employing the fourth dominant strategy type. A schematic flow chart of this strategy type is presented in Figure 6.5d.

Subjects employing this strategy type begin analogy solution by encoding the first analogy term, and then the second analogy term. Next they infer the relation between the first and second terms. The subjects then encode the third analogy term and, following this, map the relation between the first and third terms. The two answer options are then encoded. Subjects then attempt to apply from the third term to each answer option a relation analogous to the one inferred between the first and second terms. Subjects would then respond with either "A" or "B", thereby completing the analogy problem.

It is important to note that in this dominant strategy type, inference is self-terminating, but mapping and application are exhaustive. Furthermore, the mode of option scanning is alternate. No variations of this strategy type were identified.

The p ng discussion of subjects post hoc introspective reports pertaining to the solution of 1 element - 1 transformation and 3 element - 3 transformation Nondegenerate forced choice geometric analogy items reveals a number of issues relevant to the present research. Issues relating specifically to the solution of 1 element - 1 transformation Nondegenerate items will be discussed separately from issues specific to 3 element - 3 transformation Nondegenerate items.

In terms of performance components adopted and order of component execution, subjective strategy reports suggest the dominance of four strategy types for 1 element - 1 transformation Nondegenerate item solution (see Figures 6.4a - 6.4d earlier in this section for schematic flow charts of these strategy types). Since the characteristics of each of these dominant strategy types have already been discussed previously in this section, at this juncture it shall suffice to note that differences between them hinge

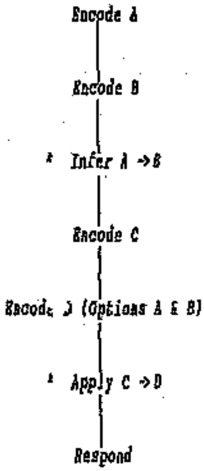

Figure 6.5 (a) Schematic flow chart of the first dominant subjective task strategy type applicable to 3 element - 3 transformation Nondegenerate item solution.

* Self-terminating process.

Encode A

Encode B

* Infer A ->B

Encode C

* Map C ->B

Encode D (Options A & B)

* Apply C ->D

Respond

Figure 6.5 (b) Schematic flow chart of the second dominant subjective task strategy type applicable to 3 element - 3 transformation Nondegenerate item solution.

* *Self-terminating process.*

Encode A

Encode B

* Infer A → B

Encode C

* Map C → B

Encode D (Options A & B)

* Apply B → D

Respond

Figure 6.5 (c) Schematic flow chart of the third dominant subjective task strategy type applicable to 3 element - 3 transformation Nondegenerate item solution.

* Self-terminating process.

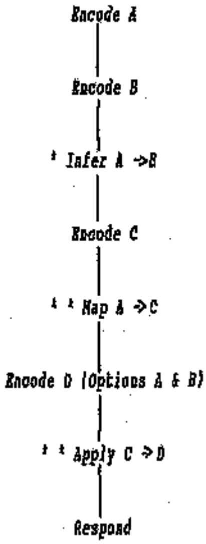

Figure 6.5 (d) Schematic flow chart of the fourth dominant subjective task strategy type applicable to 3 element - 3 transformation Nondegenerate item solution.

* Self-terminating process.

* * Exhaustive process.

upon: Firstly, the presence or a' ence of a mapping process following the encoding of the third analogy term (absent from the strategy type presented in Figure 6.4a) and, secondly, the nature of the application process. On the basis of subjective task strategy reports relating to 1 element - 1 transformation Nondegenerate items, variations of the four dominant strategy types were identified. As noted earlier in this section these variations apparently arose as a result of subjects employing eicher a self-terminating or exhaustive application process. Three variations of each of the dominant strategy types presented in Figures 6.4a and 6.4c were identified, while two variations of each of the dominant strategy types presented in Figures 6.4b and 6.4d were identified. These variations were discussed previously in this section. It is important to note that the post hoc introspective reports of subjects who employed the third variations of the dominant strategy types presented in Figures 6.4a and 6.4c revealed that order of answer options, i.e., which answer option was correct (A or B), was a determining factor of the type of application process employed. Where the first answer option was correct, subjects reporting these strategy type variations would employ a self-terminating application process, and where the second answer option was correct, these subjects would employ an exhaustive application process.

Based on subjects post hoc introspective reports regarding performance components adopted and order of component execution, it would appear that the process model presented in Figure 6.4a best defines task performance on 1 element - 1 transformation Nondegenerate forced choice geometric analogy items.

In terms of performance components adopted, order of component execution, nature of inference, mapping and application procedures (i.e., self-terminating or exhaustive), and mode of option scanning (i.e., sequential or alternate), subjective task strategy reports suggest the dominance of four strategy types for 3 element - 3 transformation Nondegenerate item solution (see Figures 6.5a - 6.5d earlier in this section for schematic flow charts of these strategy types). Since the characteristics of each of these dominant strategy types have already been discussed previously in this section, at this juncture it shall suffice to note that differences between them hinge upon: Firstly, the presence or absence of a mapping process following the encoding of the third analogy term (absent from the strategy type presented in Figure 6.5a); secondly, the nature of the mapping and application processes (self-terminating in the strategy types presented in Figures 6.5a, 6.5b and 6.5c, but exhaustive in the strategy type presented in Figure 6.5d) and, thirdly, the term compared with the two answer options in the application process (the third term in the strategy types presented in Figures 6.5a, 6.5b and 6.5d, but the second term in the strategy type presented in Figure 6.5c). As noted previously in this section no variations of these four dominant strategy types were identified. It is worthwhile noting that in terms of performance components adopted and order of component execution only, the four dominant subjective task strategy types identified from subjects post hoc introspective reports pertaining to 3 element - 3 transformation Nondegenerate items were identical to those reported for the solution of 1 element - 1 transformation Nondegenerate items. Thus, it would appear that despite the increase in both the number of elements per analogy term, as well as the number of transformations between analogy terms, in terms of performance components adopted and order of component execution, the identical four strategy types dominate. This would seem to suggest that on the basis of subjective strategy reports, for Nondegenerate forced choice geometric analogy items, increases in item complexity fail to elicit meaningful strategic variations on the part of subjects, in terms of performance components adopted and order of component execution, in order to overcome increases in mental workload and maintain high standards of task performance.

Based on subjects post hoc introspective reports regarding performance components adopted; order of component execution; nature of inference, mapping and application procedures and mode of option scanning, it would appear that the process models present . in Figures 6.5a and 6.5c best define task performance on . element - 3 transformation Nondegenerate forced choice geometric analogy items.

Of significance for present research purposes is the degree of association between subjective complexity judgements and subjects' self-reported subjective task strategy types pertaining to both examples of each analogy type. Thus, it will be of value to examine the extent to which changes in subjective item complexity judgements coincide with post hoc reports of task strategy.

A discussion of this association will be presented separately for each analogy type.

Degenerate Forced Choice Geometric Analogy Items

Table 5.5a (page 205) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 1 element Degenerate forced choice geometric analogy example. Most striking is the spread of frequencies through the stimulus complexity x task strategy matrix, with only two of the potential cells remaining vacant and these occur for complexity codes 3 (N=6) and 5 (N=1).

Binomial two-tail test results set out in Table 5.5a show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two- tail tests for each table row should be treated with caution, particularly for complexity Codes 3 to 5.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 58% of cases identifying with subjective strategy code 1.1a, discussed previously and illustrated in the form of a process model in Figure 6.1a in the section Degenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1a strategy column this complexity code association accounts for the majority (again about 58%) of 1.1a strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 67% of cases identifying with subjective strategy code 1.2a, discussed previously, and illustrated by means of a process model in Figure 6.1b in the section Degenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 1.2a strategy column this complexity code association accounts for about 41% of 1.2a strategy respondents.

Table 5.5b (page 206) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 3 element Degenerate forced choice geometric analogy example. Most noticeable is the spread of frequencies through the stimulus complexity x task strategy matrix, with only two of the potential cells remaining vacant and these occur for complexity codes 3 (N=6) and 5 (N=1).

Binomial two-tail test results set out in Table 5.5b show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two-tail tests for each table row should be treated with caution, particularly for complexity codes 3 to 5.

For complexity codes 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 55% of cases identifying with subjective strategy code 3.1a, discussed previously, and illustrated by means of a process model in Figure 6.1a in the section Degenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1a strategy column this complexity code association accounts for the majority (about 52%) of 1.3a strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 56% of cases identifying with subjective strategy code 3.2a, discussed previously, and illustrated by means of the process model in Figure 6.1b in the section Degenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 3.2a strategy column this complexity code association accounts for about 37% of 3.2a strategy respondents.

These findings reinforce the conclusions put forward in the section Stimulus Complexity and Task Performance earlier in this chapter, in that the observable partial non randomness of association between subjective task strategy reports and subjective stimulus complexity judgements points to non uniform treatment effects within the total sample population.

Semidegenerate (A:A::B:B) Forced Choice Geometric Analogy Items

Table 5.5c (page 209) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 1 element - 1 transformation Semidegenerate (A:A::B:B) forced choice geometric analogy example. Most striking is the spread of frequencies through the stimulus complexity x task strategy matrix, with only one of the potential cells remaining vacant and this occurred for complexity code 5 (N=1).

Binomial two-tail test results set out in Table 5.5c show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two-tail tests for each table row should be treated with caution, particularly for complexity codes 3 to 5.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 71% of cases identifying with subjective strategy code 1.1b, discussed previously, and illustrated by means of the process model in Figure 6.2a in the section Semidegenerate (A:A::B:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1b strategy column this complexity code association accounts for about 46% of 1.1b strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 95% of cases identifying with subjective strategy code 1.1b, discussed previously, and illustrated by means of the process model in Figure 6.2a in the section Semidegenerate (A:A::B:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1b strategy column this complexity code association accounts for about 35% of 1.1b strategy respondents.

Table 5.5d (page 211) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 3 element - 3 transformation Semidegenerate (A:A::B:B) forced choice geometric analogy example. Most noticeable is the spread of frequencies through the stimulus complexity x task strategy matrix, with only three of the potential cells remaining vacant and these occur for complexity codes 2 (N=18), 3 (N=6) and 5 (N=1).

Binomial two-tail test results set out in Table 5.5d show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two tail tests for each table row should be treated with caution particularly for complexity codes 3 and 5.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 77% of cases identifying with subjective strategy code 3.1b, discussed previously, and illustrated by means of the process model in Figure 6.2a in the section Semidegenerate (A:A::B:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1b strategy column this complexity code association accounts for about 46% of 3.1b strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of 100% of cases identifying with subjective strategy code 3.1b, discussed previously, and illustrated by means of the process model in Figure 6.2a in the section Semidegenerate (A:A::B:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1b strategy column this complexity code association accounts for about 35% of 3.1b strategy respondents.

These findings support the conclusions put forward in the section Stimulus Complexity and Task Performance earlier in this chapter in that the observable partial non randomness of association between subjective task strategy reports and subjective stimulus complexity judgements points to non uniform treatment effects within the total sample population.

Semidegenerate (A:B::A:B) Forced Choice Geometric Analogy Items

Table 5.5e (page 212) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 1 element - 1 transformation Semidegenerate (A:B::A:B) forced choice geometric analogy example. Most striking is the spread of frequencies through the stimulus complexity x task strategy matrix, with only three of the potential cells remaining vacant and these occur for complexity codes 3 (N=6), 4 (N=4) and 5 (N=1).

Binomial two-tail test results set out in Table 5.5e show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two tail tests for each table row should be treated with caution, particularly for complexity codes 3 to 5.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 61% of cases identifying with subjective strategy code 1.2c, discussed previously, and illustrated by means of the process model in Figure 6.3b in the section Semidegenerate (A:B::A:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 1.2c strategy column this complexity code association accounts for the majority (about 61%) of 1.2c strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 61% of cases identifying with subjective strategy code 1.1c, discussed previously and illustrated by means of the process model in Figure 6.3a in the section Semidegenerate (A:B::A:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1c strategy column this complexity code association accounts for about 38% of 1.1c strategy respondents.

Table 5.5f (page 214) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 3 element - 3 transformation Semidegenerate (A:B::A:B) forced choice geometric analogy example. Most noticeable is the spread of frequencies through the stimulus complexity x task strategy matrix, with only two of the potential cells remaining vacant and these occur for complexity codes 4 (N=4) and 5 (N=1).

Binomial two-tail test results set out in Table 5.5f show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the binomial two-tail tests for each table row should be treated with caution, particularly for complexity codes 3 to 5.

For complexity codes 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 68% of cases identifying with subjective strategy code 3.2c, discussed previously and illustrated by means of the process model in Figure 6.3b in the section Semidegenerate (A:B::A:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 3.2c strategy column this complexity code association accounts for the majority (about 57%) of 3.2c strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 56% of cases identifying with subjective strategy code 3.1c, discussed previously and illustrated by means of the process model in Figure 6.3a, in the section Semidegenerate (A:B::A:B) Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1c strategy column this complexity code association accounts for about 43% of 3.1c strategy respondents.

These findings support the conclusions put forward in the section Stimulus Complexity and Task Performance earlier in this chapter, in that the observable partial non randomness of association between subjective task strategy reports and subjective stimulus complexity judgements points to non uniform treatment effects within the total sample population.

Nondegenerate Forced Choice Geometric Analogy Items

Table 5.5g (page 215) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 1 element - 1 transformation Nondegenerate forced choice geometric analogy example. Most striking is the spread of frequencies through the stimulus complexity x task strategy matrix with only six of the potential cells remaining vacant and these occur for complexity codes 3 (N=6), 4 (N=4) and 5 (N=1).

Chi square analysis results set out in Table 5.5g show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the goodness of fit chi square tests for each table row should be treated with caution, particularly for complexity codes 3 to 5. Indeed even allowing for the potential inaccuracy of chi square under these conditions, results for complexity codes 3 to 5 are not inspirational with the most relevant feature being the spread of association across task strategy groups rather than the level of non randomness.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 48% of cases identifying with subjective strategy code 1.1d, discussed previously, and illustrated by means of the process model in Figure 6.4a in the section Nondegenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1d strategy column this complexity code association accounts for about 41% of 1.1d strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 83% of cases identifying with subjective strategy code 1.1d, discussed previously, and illustrated by means of the process model in Figure 6.4a in the section Nondegenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 1.1d strategy column this complexity code association accounts for about 41% of 1.1d strategy respondents.

Table 5.5h (page 217) sets out the relationship between subjective item complexity judgements and post hoc subjective reports of task strategy relating to the 3 element - 3 transformation Nondegenerate forced choice geometric analogy example. Most noticeable is the spread of frequencies through the stimulus complexity x task strategy matrix, with only six of the potential cells remaining vacant and these occur for complexity codes 3 (N=6), 4 (N=4) and 5 (N=1).

Chi square analysis results set out in Table 5.5h show the overall distribution of frequencies across strategy codes to be non random.

However, in view of the large number of matrix cells containing fewer than five observations the results of the goodness of fit chi square tests for each table row should be treated with caution, particularly for complexity codes 3 to 5. Indeed even allowing for the potential inaccuracy of chi square under these conditions, results for complexity codes 3 to 5 are not inspirational with the most relevant feature being the spread of association across task strategy groups rather than the level of non randomness.

For complexity code groups 1 and 2 however, which together account for approximately 82% of respondents, the picture is more interesting.

For complexity code group 1 the frequency distribution across task strategy groups gives an association of approximately 35% of cases identifying with subjective strategy code 3.1d, and a further 35% of cases identifying with subjective strategy code 3.3d. Both of these subjective strategies were discussed previously and illustrated by means of process models (Figure 6.5a in the case of subjective strategy code 3.1d, and Figure 6.5c in the case of subjective strategy code 3.3d) in the section

Nondegenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1d and 3.3d strategy columns this complexity code association accounts for 50% of 3.1d strategy respondents, and about 48% of 3.3d strategy respondents.

For complexity code group 2 the frequency distribution across task strategy groups gives an association of approximately 56% of cases identifying with subjective strategy code 3.1d, discussed previously, and illustrated by means of the process model in Figure 6.5a in the section Nondegenerate Subjective Task Strategy Types earlier in this chapter. Looking down the 3.1d strategy column this complexity code association accounts for about 45% of 3.1d strategy respondents.

These findings support the conclusions put forward in the section Stimulus Complexity and Task Performance earlier in this chapter in that the observable partial non randomness of association between subjective task strategy reports and subjective stimulus complexity judgements points to non random treatment effects within the total sample population.

In the context of the present research the evidence for concrete inter-group qualitative differences in information processing strategies for forced choice geometric analogy items is thus opaque merely because, for each experimental geometric analogy type, the basis for group membership is subjective and unverifiable.

The categorisation of superficially similar verbal accounts as being the same does not necessarily guarantee that the same cognitive resources allocation has occurred. To take this for granted would be to overstate the value of introspective reports in the search for regularities in cognitive processing. At this juncture, and on the evidence of partitioning data by subjective reports, it can, however, be confirmed that the data sets relating to each of the experimental analogy types reflect more than one unified set of cognitive componential processes for forced choice geometric analogy solution.

There is evidence that subjects' strategy and information processing constraints may be far more flexibly applied, particularly under conditions of varying complexity, to the forced choice geometric analogy task, more so to the Nondegenerate type, than would be suggested by the basic componential models of analogical reasoning proposed by Sternberg (1977), and discussed previously in the section Componential Models of Analogical Reasoning in Chapter 3.

Meanwhile, it is appropriate to more fully discuss the present research findings in the context of the theory and research relevant to both the analogical reasoning and mental workload paradigms, reviewed in Part 1 of this thesis.

"Componential Analysis" Revisited

The discussion of results thus far has focused on two key aspects of the present experimental design; stimulus complexity and the influence of task demands on solution strategy. It is now relevant to reconsider Sternberg's (1977) componential theory of analogical reasoning and the claims made about it, in the context of the results yielded by the present research.

It was stated in the section Aims of the Present research in Chapter 4 that the aims of the present study were twofold. Firstly, in the context of the present research findings, to investigate the generalisability of the basic componential models proposed by Sternberg (1977) as best defining task performance on Nondegenerate forced choice geometric analogy items, and secondly, propose models that best define task performance on Degenerate and Semidegenerate forced choice geometric analogy items, in terms of performance components adopted and order of component execution.

Given that process models of task performance, based on subjects' post hoc introspective reports for Degenerate, Semidegenerate and Nondegenerate forced choice geometric analogy items were presented in the section Task Structure and Solution Strategy earlier in this chapter, thereby satisfying the second of the abovementioned aims, it remains necessary, at this juncture, to evaluate the generalisability of the componential models proposed by Sternberg (1977) as best defining task performance on Nondegenerate forced choice geometric analogy items.

The four alternate componential models of analogical reasoning proposed by Sternberg (1977) were discussed previously, and illustrated by means of process models in the section Componential Models of Analogical Reasoning in Chapter 3.

It is noted by Sternberg (1977) that, based on the data yielded by his Geometric Analogy Experiment (1977), Model I (page 124) is clearly worst at accounting for subject performance on the experimental items, whereas Model III (page 128) is clearly better than the others, accounting for 70% of the variance in the data.

For present purposes, the process models developed from subjects' post hoc introspective reports pertaining to 1 element - 1 transformation and 3 element - 3 transformation Nondegenerate forced choice geometric analogy item solution, presented in the section Nondegenerate Geometric Analogy Subjective Task Strategy Types earlier in this chapter, will be evaluated against the componential models proposed by Sternberg (1977) in order to assess firstly, the generalisabilty of the latter models, and secondly, Sternberg's (1977) contention that Model III accounts better than the other models for subject performance on Nondegenerate forced choice geometric analogy items.

Separate evaluations will be presented for the 1 element - 1 transformation Nondegenerate process models and the 3 element - 3 transformation Nondegenerate process models.

1 Element - 1 Transformation Nondegenerate Forced Choice Geometric Analogy Process Models

The process models developed from subjects' post hoc introspective reports relating to 1 element - 1 transformation Nondegenerate item solution shall be evaluated against the componential models proposed by Sternberg (1977) in terms of performance components adopted and order of component execution.

The process model presented in Figure 6.4a (page 296) corresponds closely with each of the componential models proposed by Sternberg (1977). A major difference between this process model and the models proposed by Sternberg (1977) however,. is the absence of the mapping process incorporated into each of the Sternberg models, immediately following the encoding of the third analogy term.

The process model presented in Figure 6.4b (page 297) corresponds identically with the componential models proposed by Sternberg (1977), in terms of performance components adopted and order of component execution. A subtle difference however, is that whereas the mapping procedure incorporated into the Sternberg models involves identification of the relation between the first and third terms of the analogy, the mapping procedure incorporated into the process model presented in Figure 6.4b involves the identification of the relation between the third and second terms of the analogy.

The process model presented in Figure 6.4c (page 298) corresponds identically with the componential models proposed by Sternberg (1977), in terms of performance components adopted and order of component execution. Two noticeable differences do however, exist between this process model and the Sternberg models. Firstly, whereas the mapping procedure incorporated into the Sternberg models involves identification of the relation between the first and third terms of the analogy, the mapping procedure incorporated into the process model presented in Figure 6.4c involves the identification of the relation between the third and second terms of the analogy. Secondly, whereas the application procedure incorporated into the Sternberg models involves comparison of the third analogy term with each answer option, the application procedure incorporated into the process model presented in Figure 6.4c involves comparison of the second analogy term with each answer option.

The process model presented in Figure 6.4d (page 299) corresponds identically with the componential models proposed by Sternberg (1977), in terms of performance components adopted and order of component execution. No differences whatsoever were identified between this process model and the Sternberg models.

In general the process models representative of subjects' performance on 1 element - 1 transformation Nondegenerate items, presented in Figures 6.4a - 6.4d, correspond closely with the Sternberg models in terms of performance components adopted and order of component execution. However, closer examination of the inference, mapping and application procedures incorporated into these process models, in particular the actual operations involved in these procedures, reveals the existence of variations between three of these models (i.e., those presented in Figures 6.4a, 6.4b and 6.4c) and the Sternberg models, whilst the process model presented in Figure 6.4d corresponds identically with the Sternberg models as they would apply to 1 element - 1 transformation Nondegenerate forced choice geometric analogy item solution. However, it is significant to note that this process model (strategy type) was reportedly employed by only 5% (3/60) of the subjects.

3 Element - 3 Transformation Nondegenerate Forced Choice Geometric Analogy Process Models

It will be recalled from the section Nondegenerate Geometric Analogy Subjective Task Strategy Types earlier in this chapter that in terms of performance components adopted and order of component execution, the dominant subjective task strategy types identified from subjects' post hoc introspective reports relating to 3 element - 3 transformation Nondegenerate items (illustrated by the process models presented in Figures 6.5a - 6.5d) were identical to those reported for the solution of 1 element - 1 transformation Nondegenerate items (illustrated by the process models presented in Figures 6.4a - 6.4d). Given this congruence between 1 element - 1 transformation and 3 element - 3 transformation Nondegenerate strategy types, and since the process models representative of 1 element - 1 transformation Nondegenerate item solution have already been compared with Sternberg's (1977) componential models in terms of performance components adopted and order of component execution, it is not necessary to compare the 3 element - 3 transformation Nondegenerate process models with Sternberg's models on the same dimensions. Rather, the 3 element - 3 transformation Nondegenerate process models will be evaluated against the componential models proposed by Sternberg (1977) on the dimensions of nature of inference, mapping and application procedures (i.e., self-terminating or exhaustive), and mode of option scanning (i.e., sequential or alternate).

It will be noted that the nature of the inference and application procedures (i.e., self-terminating), and the mode of option scanning (i.e., alternate) of the process model presented in Figure 6.5a (page 303) correspond most closely with the related procedures in Model IV proposed by Sternberg (1977). The mapping procedure incorporated into Sternberg's Model IV is however, absent from this process model.

The nature of the inference, mapping and application procedures (i.e., self-terminating), and the mode of option scanning (i.e., alternate) of the process model presented in Figure 6.6b (page 304) correspond most closely with the related procedures in Model IV proposed by Sternberg (1977). The major variation between this process model and Sternberg's Model IV is the difference in the actual operations involved in their respective mapping procedures. This difference was discussed in the preceding section 1 Element - 1 Transformation Nondegenerate Forced Choice Geometric Analogy Process Models.

The nature of the inference, mapping and application procedures (i.e., self-terminating), and the mode of option scanning (i.e., alternate) of the process model presented in Figure 6.5c (page 305) correspond most closely with the related procedures in Model IV proposed by Sternberg (1977). The major variations between this process model and Sternberg's Model IV are the differences in the actual operations involved in their respective mapping and application procedures. These differences were discussed in the preceding section 1 Element - 1 Transformation Nondegenerate Forced Choice Geometric Analogy Process Models.

The nature of the mapping and application procedures (i.e., exhaustive), and the mode of option scanning (i.e., alternate) of the process model presented in Figure 6.5d (page 306) correspond most closely with the related procedures in Model I proposed by Sternberg (1977). The major variation between this process model and Sternberg's Model I centres on the nature of the inference procedure, which in the former model is self-terminating, and in the latter model exhaustive.

On the basis of performance components adopted, order of component execution, nature of inference, mapping and application procedures and mode of option scanning, the process models presented in Figures 6.5a - 6.5d correspond reasonably well with certain of the componential models proposed by Sternberg (1977). The process models presented in Figures 6.5a, 6.5b and 6.5c correspond most closely with Model IV proposed by Sternberg (1977), while the process model presented in Figure 6.5d corresponds most closely with Model I proposed by Sternberg (1977). However, given the variations identified between the experimental process models and the Sternberg models with which they most closely correspond, it is evident that none of the models proposed by Sternberg (1977) fully accounts for the present performance data pertaining to 3 element - 3 transformation Nondegenerate forced choice geometric analogy item solution.

Clearly the similarities in experimental design and execution between this research and Sternberg's (1977) Geometric Analogy Experiment have contributed significantly to the broad correspondence of present performance data with that produced by Sternberg's (1977) study. However, of equal importance, there are a number of experimental reasons why data from the present research may not directly match that from other research investigating the performance components involved in geometric analogy problem solving (e.g., Sternberg, 1977; Mulholland et al., 1980; Pellegrino and Glaser, 1980; Pellegrino and Kail, 1982), i.e., the use of two precueing conditions (a procedure only employed by Sternberg (1977)); the use of a large number of truly experimentally naive subjects; the controlled use of instructions, and the investigation of within, as well as between subject performance on items of varying complexity. Each of these features in the design of the present study will likely produce some departure from the usual expected geometric analogy problem solving results.

However, these design features alone fail to provide an explanation of the findings. They serve merely to reinforce the intention that where there is no experimenters' bias and where there has been an attempt to minimise experimenter effects, there is less likelihood of deriving a clear, uniform set of results.

To summarise the discussion so far, there are indications from the inspection of results partitioned by subjective report and judgement codes that there are non random effects attributable to strategy differences and stimulus complexity associations. However, there is no apparent explanation as to whether these effects are meaningful, and if so, whether they could at all be attributed to the level of mental workload experienced by subjects during task performance. This issue will be returned to in the section Componential Analysis and Mental Workload later in this chapter.

Despite the evidence reviewed in the previous two sections of this chapter (Stimulus Complexity and Task Performance and Task Structure and Solution Strategy) it appears that the use of subjective reports is unlikely to help elucidate the range of geometric analogy processing strategies masked within the data relevant to each geometric analogy type.

It would therefore be meaningless to categorise each sub group as a specific strategy type as if it represented some distinct type of information processing strategy. Such naive distinctions would serve only to cloud the issue further.

In an attempt to overcome this impasse it will be useful to conduct a more rigorous and less prescriptive investigation of the patterns that exist within the data matrices as they apply to each of the experimental geometric analogy types, and to examine the results of the cluster analysis procedures reported in Chapter 5.

Clusters and Stimulus Properties

It will be recalled fro the section Subjective Influences and Cluster Analysis in Chapter 4 that the essential value of clustering algorithms and the cluster analysis concept is the avoidance of having to partition data sets on the basis of previously decided experimental conditions.

In the section The Cluster Analysis Procedures in Chapter 5 it was stressed that part of the justification for applying a cluster analysis to the main data sets was the assumption that there existed variation, structure and pattern within each of the data matrices and that this was the result of the experimental independent variables. The value of cluster analysis techniques such as the FASTCLUS algorithm is precisely in the avoidance of a priori classification of data subsets and a predilection for a neat linear, sequential constraint to the explanation of any such data subsets; particularly so when the predilection is shaped by the weak evidence of subjects' verbal reports of introspective strategy.

From the section The Cluster Analysis Procedures in Chapter 5, it will be recalled that the FASTCLUS algorithm produced a consistent and robust cluster solution for each of the four data matrices (see Table 5.6a (page 224), Table 5.7a (page 233), Table 5.8a (page 240) and Table 5.9a (page 247); so much so that these cluster solutions remained unchanged despite the use of techniques designed to permit the algorithm to produce up to twenty clusters.

As it is an essential assumption that each of the four cluster solutions are directly related to the pattern or structure inherent in each of the four data matrices and thus directly attributable to the effects of the independent variables in each of the factorial experimental designs, it follows that any inspection for an information processing basis for these solutions should concentrate on the quantitative and qualitative effects; main, interaction and contrast, of these variables.

The more obvious explanation for each of the cluster solutions, i.e., that the partitions were caused by variables such as handedness or gender, has been discounted previously in Chapter 5. Similarly the possibility that subjective judgements about task strategy and item complexity might be the basis for each of the cluster solutions is not supported by either binomial two-tail tests or chi square tests of association as reported in Chapter 5.

For present purposes a separate investigation will be conducted on the cluster solutions relevant to each experimental geometric analogy type.

The Degenerate Forced Choice Geometric Analogy Cluster Solution

It will be recalled from the section Degenerate Forced Choice Geometric Analogy Cluster Solutions in Chapter 5, that the FASTCLUS algorithm produced a consistent and robust two cluster solution from the Degenerate data matrix (see Table 5.6a on page 224, and associated text).

A useful place to begin the investigation of the effects of the independent variables in the Degenerate factorial experimental design, is the inspection of means in Table 5.6b (page 227).

Most noticeable is that the means for cluster 2 (N=56) are always representative of much faster response times per factorial condition than the means for cluster 1 (N=4), typically displaying about a 55% differential. Also evident, for both clusters, is that the mean response time for items presented in the two cue condition are consistently faster than those for items presented in the zero cue condition and, furthermore, that an increase in the number of elements per term was directly proportional to an increase in response times for items presented in both precueing conditions. Thus, it would appear that the response time effect, first observed in Table 5.1a (page 180), is still in evidence.

Assumably the difference in rapidity between cluster 1 and cluster 2 response patterns is one of the strong reasons for the clustering algorithm's execution of the cluster solution, however, closer examination of the effects of the Degenerate experimental independent variables indicates that the speed of decision making alone does not appear to be the sole basis for the solution.

The first essential observation about the two clusters is that whereas cluster 2 displays a highly significant main effect for Cue (precueing condition), cluster 1 displays a mild, non significant main effect (see Table 5.6c page 230). A more detailed inspection of this effect through the Cue contrasts in Table 5.6d (page 231) indicates that for cluster 2 there is a highly significant difference between Cue 1 and 2, whilst for cluster 1 there is only a mild, non significant difference between Cue 1 and 2. This distinction is of qualitative interest and will be returned to in the section Degenerate Analogy Clusters and Individual Differences later in this chapter.

The second essential differences is the indication in Table 5.6c of a highly significant main effect for Element (number of elements per term) in cluster 2 but only a mild, non significant main effect for Element in cluster 1. More detailed inspection of this effect through the Element contrasts in Table 5.6d indicates that each of the three Element conditions 1, 2 and 3, produce significantly different response time effects within cluster 2, whilst for cluster 1 there are noticeable but non significant differences between Elements 1 and 2 and Elements 2 and 3, but there is a mild, non significant difference between Elements 1 and 3. Expressed more succinctly, $d1 - 2 < d2 - 3 < d1 - 3$ (where d = difference between) which suggests a temporary succession of strategy modification in cluster 1. This distinction, though strictly non significant in terms of predetermined alpha levels, is of qualitative interest and will be returned to in the section Degenerate Analogy Clusters and Individual Differences later in this chapter.

Similarly, from Table 5.6c (page 230), the distinction between clusters for a highly significant Cue x Element interaction for cluster 2 is worthy of further qualitative speculation, particularly in view of the noticeable but non significant presence of the effect in cluster 1. Again this will be returned to in the section Degenerate Analogy Clusters and Individual Differences later in this chapter.

The Semidegenerate (A:A::B:B) Forced Choice Geometric Analogy Cluster Solution

It will be recalled from the section Semidegenerate (A:A::B:B) Forced Choice Geometric Analogy Cluster Solutions in Chapter 5, that the FASTCLUS algorithm produced a consistent and robust three cluster solution from the Semidegenerate (A:A::B:B) data matrix (see Table 5.7a on page 233, and associated text).

A useful place to begin the investigation of the effects of the independent variables in the Semidegenerate (A:A::B:B) factorial experimental design, is the inspection of means in Table 5.7b (pages 234 to 236).

Most noticeable is that the means for cluster 2 (N=24) are always representative of much faster response times per factorial condition than the means for cluster 1 (N=33) (typically displaying about a 22% differential), which in turn are always representative of faster response times per factorial condition than the means for cluster 3 (N=3) (typically displaying about a 58% differential). Also evident, for each of the three clusters, is that the mean response times for items presented in the two cue condition are consistently faster than those for items presented in the zero cue condition and, furthermore, that increases in both the number of elements per term, and number of transformations between terms are directly, proportional to increases in response times for items presented in both precueing conditions. It is important to note that an increase in the number of transformations between terms results in a more significant increase in response times than does an increase in the number of elements per term. Apparently evaluation of transformations took more time than did element analysis and was the primary source of increases in response time. Thus, it would appear that the response time effect, first observed in Table 5.1b (page 181), is still in evidence.

Assumably the difference in rapidity between cluster 1, cluster 2 and cluster 3 response patterns is one of the strong reasons for the clustering algorithm's execution of the cluster solution, however closer examination of the effects of the Semidegenerate (A:A::B:B) experimental independent variab[illegible]s indicates that the speed of decision making alone does not appear to be the sole basis for the solution.

The first essential observation about the three clusters is that whereas clusters 1 and 2 display a highly significant main effect for Cue (precueing condition), Cluster 3 displays a noticeable but non significant main effect for Cue (Table 5.7c; page 238). A more detailed inspection of this effect through the Cue contrasts in Table 5.7d (page 239) indicates that for clusters 1 and 2 there is a highly significant difference between Cue 1 and 2, whilst for cluster 3 there is a noticeable but non significant difference between Cue 1 and 2. This distinction is of qualitative interest and will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

The second essential difference is the indication in Table 5.7c of a highly significant main effect for Element (number of elements per term) in clusters 1 and 2, but only a mild non significant main effect for Element in cluster 3. A more detailed inspection of this effect through the Element contrasts in Table 5.7d indicates that each of the three Element conditions 1, 2 and 3, produce significantly different response tim[illegible] effects within clusters 1 and 2, whilst i[illegible] cluster 3, t[illegible] insignificant differences between Elements 1 a[illegible]essed more succinctly; d2 - 3 < d1 - 2 < d[illegible]e d = difference between) which suggests a temp[illegible]ccession of strategy modification in cluster 3. [illegible]is distinction, though strictly non significant in terms of predetermined alpna levels, is of qualitative interest and will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

Similarly, from Table 5.7c (page 238), the distinction between clusters for a mild, non significant Cue x Element interaction for cluster 1 is worthy of further qualitative speculation, particularly in view of the noticeable but non significant presence of the effect in cluster 2, and absence of the effect in cluster 3. Again this will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

Of more distinction is the indication in Table 5.7c of a highly significant main effect for Trans (number of transformations between terms) in clusters 1 and 2 but only a mild, non significant main effect for Trans in cluster 3. A more detai[illegible] inspection of this effect through the Trans contrasts in Table 5.7d indicates that for clusters 1 and 2 there exist highly significant differences between Trans 1 and 2, whilst for Cluster 3 there is a mild, non significant difference between Trans 1 and 2. This distinction is of qualitative interest and will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

Also of interest, from Table 5.7c, is the distinction between clusters for a non significant Cue x Trans interaction for cluster 1, particularly in view of the absence of the effect from clusters 2 and 3. This distinction is worthy of qualitative speculation and will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

Of further interest, also from Table 5.7d is the distinction between clusters for a mildy significant Element x Trans interaction for cluster 2, particularly in view of the mild, non significant presence of the effect in cluster 1, and noticeable but non significant presence of the effect in cluster 3. This distinction is of qualitative interest and will be returned to in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

The Cue x Element x Trans interaction (Table 5.7c) proves insignificant for Clusters 1, 2 and 3. This finding will receive further attention in the section Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences later in this chapter.

The Semidegenerate (A:B::A:B) Forced Choice Geometric Analogy Cluster-Solution

It will be recalled from the section Semidegenerate (A:A::B:B) Forced Choice Geometric Analogy Cluster Solutions in Chapter 5, that the FASTCLUS algorithm produced a consistent and robust two cluster solution from the Semidegenerate (A:B::A:B) data matrix (see Table 5.8a on page 240, and associated text).

A useful place to begin the investigation of the effects of the independent variables in the Semidegenerate (A:B::A:B) factorial experimental design, is the inspection of means in Table 5.8b (page 242 to 243). Most noticeable is that the means for cluster 2 (N=57) are always representative of much faster response times per factorial condition than the means for cluster 1 (N=3), typically displaying about a 55% differential. Also evident, for both clusters, is that mean response times for items presented in the two cue condition are consistently faster than those for items presented in the zero cue condition and, furthermore, that increases in both the number of elements per term, and number of transformations between terms are directly proportional to increases in response times for items presented in both precueing conditions. It is important to note that an increase in the number of transformations between terms results in a more significant increase in response times than does an increase in the number of elements per term. Apparently evaluation of transformations took more time than did element analysis and was the primary source of increases in response time. Thus, it would appear that the response time effect, first observed in Table 5.1c (page 182), is still in evidence.

Assumably the difference in rapidity between cluster 1 and cluster 2 response patterns is one of the strong reasons for the clustering algorithm's execution of the cluster solution, however, closer examination of the effects of the Semidegenerate (A:B::A:B) experimental independent variables indicates that the speed of decision making alone does not appear to be the sole basis for the solution.

The first essential observation about the two clusters is that whereas cluster 2 displays a highly significant main effect for Cue (precueing condition), cluster 1 displays a mild, non significant main effect (Table 5.8c; page 245). A more detailed inspection of this effect through the Cue contrasts in Table 5.8d (page 246) indicates that for cluster 2 there is a highly significant difference between Cue 1 and 2, whilst for cluster 1 there is only a mild, non significant difference between Cue 1 and 2. This is of qualitative interest and will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

The second essential difference is the indication in Table 5.8c of a highly significant main effect for Element (number of elements per term) in cluster 2 but only a noticeable, non significant main effect for Element in cluster 1. A more detailed inspection of the effect through the Element contrasts in Table 5.8d indicates that each of the three Element conditions 1, 2 and 3, produce significantly different response time effects within cluster 2, whilst for cluster 1 there are no real differences evident from each pair comparison. This distinction is worthy of further qualitative speculation and will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

Similarly, from Table 5.8c, the distinction between clusters for a highly significant Cue x Element interaction effect for cluster 2 is of qualitative interest, particularly in view of the absence of the effect in cluster 1. Again this will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

Of more distinction is the indication in Table 5.8c of a highly significant main effect for Trans (number of transformations between terms) in cluster 2 but only a noticeable, non significant main effect for Trans in cluster 1. A more detailed inspection of this effect through the Trans contrasts in Table 5.8d indicates that for cluster 2 there is a highly significant difference between Trans 1 and 2, whilst for cluster 1 there is a noticeable, non significant difference between Trans 1 and 2. This distinction is worthy of further qualitative speculation and will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

Also of importance, from Table 5.8c, is the distinction between clusters for a mildly significant Cue x Trans interaction for cluster 2, particularly in view of the absence of the effect in cluster 1. This distinction is of qualitative interest and will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

Of further interest, also from Table 5.8c, is the distinction between clusters for a highly significant Element x Trans interaction for cluster 2, particularly in view of the absence of the effect in cluster 1. This distinction warrants further qualitative speculation and will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

Lastly, from Table 5.8c, the distinction between clusters for a highly significant Cue x Element x Trans interaction for cluster 2 is of qualitative interest, given the absence of the effect in cluster 1. Again this will be returned to in the section Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences later in this chapter.

The Nondegenerate Forced Choice Geometric Analogy Cluster Solution

It will be recalled from the section Nondegenerate Forced Choice Geometric Analogy Cluster Solutions in Chapter 5, that the FASTCLUS algorithm produced a consistent and robust three cluster solution from the Nondegenerate data matrix (see Table 5.9a on page 247, and associated text).

A useful place to begin the investigation of the effects of the independent variables in the Nondegenerate factorial experimental design, is the inspection of means in Table 5.9b (pages 249 to 251).

Most noticeable is that the means for cluster 2 (N=24) are always representative of much faster response times per factorial condition than the means for cluster 1 (N=31) (typically displaying about a 22% differential), which in turn are always representative of faster response times per factorial condition that the means for cluster 3 (N=5) (typically displaying about a 40% differential). Also evident, for each of the three clusters, is that mean response times for items presented in the two cue condition are consistently faster than those for items presented in the zero cue condition and furthermore, that increases in both the number of elements per term, and number of transformations between terms are directly proportional to increases in response times for items presented in both precueing conditions. It is important to note that an increase in the number of transformations between terms results in a more significant increase in response times than does an increase in the number of elements per term. Apparently evaluation of transformations took more time than did element analysis and was the primary source of increases in response time. Thus it would appear that the response time effect, first observed in Table 5.1d (page 183), is still in evidence.

Assumably the difference in rapidity between cluster 1, cluster 2 and cluster 3 response patterns is one of the strong reasons for the clustering algorithm's execution of the cluster solution however, closer examination of the effects of the Nondegenerate experimental independent variables indicates that speed of decision making alone does not appear to be the sole basis for the solution.

The first essential observation about the three clusters is that all three display a highly significant main effect for Cue (precueing condition) (see Table 5.9c page 253). A more detailed inspection of this effect through the Cue contrast comparison in Table 5.9d (page 254) reveals that both of the Cue conditions produce significantly different response time effects within each cluster.

The second essential difference is the indication in Table 5.9c of a highly significant main effect for Element (number of elements per term) in all three clusters. A more detailed investigation of this effect through the Element contrasts in Table 5.9d indicates that each of the three Element conditions 1, 2 and 3, produce significantly different response time effects within cluster 1 and 2 whilst for cluster 3, there is a mild non significant difference between Elements 1 and 2 and mild significant differences between Elements 1 and 3 and Elements 2 and 3. Expressed more succinctly, d1-2 < d2-3 < d1-3 (shere d = difference between), which suggests a temporary succession of strategy modification in cluster 3. This distinction is of qualitative interest and will be returned to in the section Nondegenerate Analogy Clusters and Individual Differences later in this chapter.

Similarly, from Table 5.9c, the distinction between clusters for a highly significant Cue x Element interaction for cluster 1 is worth of further qualitative speculation, particularly in view of the mildly significant presence of the effect in cluster 2 and the non significant presence of the effect in cluster 3. Again this will be returned to in the section Nondegenerate Analogy Clusters and Individual Differences later in this chapter.

Of further distinction is the indication in Table 5.9c of a highly significant main effect for Trans (number of transformation between terms) in all three clusters. A more detailed investigation of this effect through the Trans contrasts in Table 5.9d indicates that each of the three Trans conditions 1, 2 and 3, produce significantly different response time effects within clusters 1 and 2, whilst for cluster 3 there is a mild, non significant difference between Trans 1 and 2, and mildly significant differences between Trans 1 and 3 and Trans 2 and 3. Expressed more succinctly, d1 - 2 < d2 - 3 < d1 - 3 (where d = difference between), which suggests a temporary succession of strategy modification in cluster 3. This distinction is of qualitative interest and will be returned to in the section Nondegenerate Clusters and Individual Differences later in this chapter.

Also of interest, from Table 5.9c, is the distinction between clusters for a highly significant Cue x Trans interaction for clusters 1 and 2, particularly in view of the mild, non significant presence of the effect in cluster 3. This distinction is of qualitative interest and will be returned to in the section Nondegenerate Analogy Clusters and Individual Differences later in this chapter.

Of further importance, also from Table 5.9c, is the distinction between clusters for a highly significant Element x Trans interaction for clusters 1 and 2, particularly in view of the noticeable but non significant presence of the effect in cluster 3. This distinction warrants further qualitative speculation and will be returned to in the section Nondegenerate Analogy Clusters and Individual Differences later in this chapter.

Lastly, from Table 5.9c, the distinction between clusters for a highly significant Cue x Element x Trans interaction for clusters 1 and 2 is of qualitative interest, given the absence of the effect in cluster 3. Again this will be returned to in the section Nondegenerate Analogy Clusters and Individual Differences later in this chapter.

As noted throughout this section, the points raised in the discussions concerning the cluster solutions relevant to each of the experimental geometric analogy types, will receive further attention in the section Clusters and Individual Differences next in this chapter, in the context of the wider implications for an information processing foundation for cluster membership.

A point of major concern for the present research objectives is that most attempts in psychology to identify individual differences in cognitive task performance in general, and analogy task performance in particular (e.g., Sternberg 1977) have tended to assume one a priori approach to task completion and have therefore, to a large extent, neglected to pay attention to qualitative variations in task performance (Just and Carpenter, 1985).

Even different versions of the same psychometric test may elicit different strategies (Just and Carpenter, 1985) but, because of the dominant tendency to analyse performance through factor analytic techniques or through the equally assumptive approaches of "cognitive components" (Sternberg, 1977) or "cognitive correlates" (Hunt, Frost and Lunnenborg, 1973), may still be described as essentially identical in the psychometric literature (Karlins, Schuerhoff and Kaplan, 1967).

It may well occur that contrasting strategy selection on the part of subjects is simply not contemplated. Differences are still treated quantatively at the expense of qualitative investigation and the interpretation of strategy changes and alterations, both within and between individuals, is subsequently restricted.

The tendency to oversimplify task demands and data classification, because of theoretical constraints, has served to impair previous research into the component cognitive processes involved in analogical problem solving (e.g., Sternberg, 1977).

More explicitly, as noted in the section Problems with Componential Analysis in Chapter 3, the scope for variation is restricted within models based on formal expectations about task structure and the sequence of task components and processing steps. Consequently, explanations and descriptions are bound by the prescriptive terms of the models themselves.

In the section Subjective Influences on Cognitive Task Performance in Chapter 4, reservations were also raised about the value of forming theories of individual differences in analogical reasoning based on the investigation of individuals' performance data from small groups, such as *N* = 24 (Sternberg, 1977) or *N* = 28 (Mulholland et al., 1980). It is the contention of this thesis that such sample sizes are insufficient to facilitate the application of a suitable data reduction technique for the purpose of identifying the range of solution strategies available for analogy task solution in general, and geometric analogy task solution in particular.

Such self fulfilling approaches are further contaminated by the use of hypothesis sophisticated subjects who have undergone implicit strategy priming (e.g., Sternberg, 1977), and explanatory predilection on the part of researchers in the field.

In the present study, whilst care was taken to maintain a level of subject naivety and to overcome the shortcomings associated with small groups of subjects by use of a much larger sample, the collection of data for subjective item complexity and strategy and its use in partitioning the data set still retains the same restrictions for explanation.

Whilst these subjective code groupings in themselves were, partially at least, non random, the relationship between subjective groupings and performance data is generally less compelling. Thus, as discussed in the section "Componential Analysis" Revisited earlier in this chapter, whilst the subjective codes do provide some evidence for non randomness of between group differences, the non exacting basis for partition and the lack of definitive performance differences between sub groups does not make for an attractive foundation for speculation or theory development in the exploration of geometric analogy problem solving.

In contrast the cluster solutions produced for each of the experimental analogy types suggest something less interpretation dependent. Whilst there are definitive clusters for each analogy type, they do not, apart from the obvious distinction of rapidity between cluster response patterns invite an interpretation through any of the usual non explanatory dichotimies such as handedness gender, etc. For each analogy type then, it is the subtle differences between cluster properties, rather than their similarities, that should be the focus of further qualitative speculation.

In addition, each of the clu tering solutions is based upon calculable statistical regularities (in squared Euclidean distance) which do not appeal to catagorical expectations formed from prior research findings. The cluster solutions do not appear either to be associated wi.n introspective reports or judgements and there is consequently no real compulsion to accommodate these into any investigation of the information processing constraints on geometric analogy task performance.

It remains essential to ascertain the extent to which the FASTCLUS algorithm can be trusted; the extent to which the cluster solution can be validated and the extent to which the differences in cluster response patterns for each analogy type are an artefact of simple statistical procedures.

One candidate argument would be that the groupings for each analogy type were a reflection of merely fast-slow partitioning of the columns of the respective data matrices. Under this answer observed differences in ANOVA, CONTRAST and PROFILE procedures would not represent a valid solution and would not therefore represent meaningful differences in geometric analogy information processing.

Alternatively, if the FASTCLUS algorithm forms clusters on the basis of (Euclidean) spatial separation then the formation of a consistent and robust cluster solution for each geometric analogy type, where clusters are separated by distance representative of speed differences, is perhaps inevitable. What is not inevitable is that for each experimental analogy type exactly the same cluster solutions would endure despite the algorithm being instructed, through the specification of maximum initial seeds, to select cluster seeds of every number from two to twenty. This would appear to suggest that the distance separation between the clusters (comprising the cluster solutions for each analogy type) is not an artefact but a very real statistical regularity in each of the four data sets. It is the contention of this thesis that such evidence of statistical regularity must be regarded as the product of subjects' information processing constraints as revealed through the experimental task demands.

The evidence from the analysis reported in the section the Cluster Analysis Procedures in Chapter 5, indicates therefore that there may be a definitive qualitative and quantitative distinction to be made in terms of the information processing constraints operating for the membership of the clusters comprising the cluster solutions produced for each analogy type.

A separate discussion will be presented for the cluster solutions relevant to each of the experimental analogy types.

Degenerate Analogy Clusters and Individual Differences

Based on the cluster solution produced for this analogy type, one scenario might be that in cluster 1, where there is mild non significant evidence for a Cue 2 < Cue 1 effect (where Cue 2 = two cue precueing condition, and Cue 1 = zero cue precueing condition), mildly significant evidence for a 1 Element < 2 Element < 3 Element effect (where Element = number of elements per analogy term), a noticeable but non significant Cue x Element interaction effect, together with a comparatively long overall response latency for all conditions, cluster members are operating on a comparatively slow, comparatively unstable strategy which, while appearing responsive to variations in the number of elements per analogy term, is only mildly sensitive to the amount of precueing information provided, with the effects of these factors, i.e., Cue and Element, appearing to be independent and additive rather than interactive. Furthermore, this strategy appears to be subject to progressive modification over time (Element related main and interaction effects). Perhaps here the Element factor related effects indicate strategy refinement or learning rather than strategy alteration and may therefore be in keeping with the item familiarity effects reported by Sternberg (1985).

The strategy being applied by cluster 2 is somewhat different. Statistically significant evidence for a stable Cue 2 < Cue 1 effect, a stable 1 Element < 2 Element < 3 Element effect, and a statistically significant Cue x Element interaction effect, together with a faster response latency for all factorial conditions, suggests that the strategy employed by cluster 2 members is quicker, more stable, and more sensitive to variations in both the amount of precueing information provided and variations in the number of elements per analogy term, with the effect of these factors, i.e., Cue and Element being highly interactive.

Thus the relative speeds between the Degenerate analogy clusters appear to be accompanied by noticeable differences in information processing constraints that are not imposed by demand characteristics but by task demands.

Semidegenerate (A:A::B:B) Analogy Clusters and Individual Differences

Based on the cluster solution produced for this analogy type, one possibility might be that in cluster 1, where there is statistically significant evidence for a stable Cue 2 < Cue 1 effect (where Cue 2 = two cue precueing condition, and Cue 1 = zero cue precueing condition), a stable 1 Element < 2 Element < 3 Element effect (where Element = number of elements per analogy term), a stable 1 Trans < 3 Trans effect (where Trans = number of transformations between analogy terms), and to a lesser extent non significant interaction effects for Cue x Element, Cue x Trans and Element x Trans together with a comparatively long overall response latency for all conditions, cluster members are operating on a comparatively slow, comparatively stable strategy which is sensitive to the amount of precueing information provided, as well as variations in both the number of elements per analogy term and number of transformations between analogy terms. Furthermore, the Cue, Element and Trans factor related effects appear to be independent and additive rather than interactive.

The strategy being applied by cluster 2 is probably similar. The evidence of the same Cue 2 < Cue 1 effect observed in cluster 1, as well as the same 1 Element < 2 Element < 3 Element effect, the same 1 Trans < 3 Trans effect, and a similar non significant interaction effect for Cue x Element, is all too similar in properties to the features identified in cluster 1. A mildly significant Element x Trans interaction effect for cluster 2 serves as the only distinguishing feature between it and cluster 1. Thus it would appear that the noticeable (and significantly) faster response times recorded for cluster 2 members, over all factorial conditions, constitute the major reason for the clustering algorithm's separating them from cluster 1 members. The same explanation cannot be offered for the clustering algorithm's separation of cluster 3 members from both cluster 1 and cluster 2 members.

The strategy ..'ng applied by cluster 3 members is somewhat different to those applied by cluster 1 and cluster 2 members. Mild non significant evidence for Cue 2 < Cue 1, 1 Element < 2 Element < 3 Element and 1 Trans < 3 Trans item complexity main effects, a non significant Element x Trans interaction effect together with a very much slower response latency for all factorial conditions, suggests that the strategy employed by cluster 3 members is slower, less stable, less responsive to the amount of precueing information provided, and less sensitive to variations in both the number of elements per analogy term and number of transformations between analogy terms, than the strategies employed by either cluster 1 or cluster 2 members. Furthermore, this strategy appears to be subject to progressive modification over time (Element related main and interaction effects). Perhaps here the Element factor related effects indicate strategy refinement or learning rather than strategy alteration and may therefore be in keeping with the item familiarity effects reported by Sternberg (1985). Furthermore, the Cue, Element and Trans factor related effects appear to be independent and additive rather than interactive.

Thus the relative speeds between Semidegenerate (A:A::B:B) analogy clusters appear to be accompanied by both subtle differences (between cluster 1 and cluster 2) and significant differences (between clusters 1 and 2 and cluster 3) in information processing constrants that are not imposed by demand characteristics but by task demands.

Semidegenerate (A:B::A:B) Analogy Clusters and Individual Differences

Based on the cluster solution produced for this analogy type, one scenario might be that in cluster 1, where there is mild non significant evidence for a Cue 2 < Cue 1 effect (where Cue 2 = two cue precueing condition, and Cue 1 = zero cue precueing condit. .), noticeable but non significant evidence for both a 1 Element < 2 Element < 3 Element effect (where Element = number of elements per analogy term) and a 1 Trans < 3 Trans effect (where Trans = number of transformations between analogy terms), together with a comparatively long overall response latency for all conditions, cluster members are operating on a comparatively slow, comparatively unstable strategy which, while appearing mildly responsive to the amount of precueing information provided, is only slightly sensitive to variations in both the number of elements per analogy term and the number of transformations between analogy terms. Moreover the Cue, Element and Trans factor related effects appear to be independent and additive rather than interactive.

The strategy being applied by cluster 2 is somewhat different. Statistically significant evidence for a stable Cue 2 < Cue 1 effect, a stable 1 Element < 2 Element < 3 Element effect, a stable 1 Trans < 3 Trans effect, and significant interaction effects for Cue x Element, Cue x Trans, Element x Trans and Cue x Element x Trans, together with a faster response latency for all factorial conditions, suggest that the strategy employed by cluster 2 members is quicker, more stable, more responsive to the amount of precueing information provided, and more sensitive to both the number of elements per analogy term an. the number of transformations between analogy terms. Furthermore, the Cue, Element and Trans factor related effects appear to be highly interactive.

Thus the relative speeds between the Semidegenerate (A:B::A:B) analogy clusters appear to be accompanied by noticeable differences in information processing constraints that are not imposed by demand c . ·eristics but by task demands.

Nondegenerate Analogy Clusters and Individual Differences

Based on the cluster solution produced for this analogy type, one possibility might be that in cluster 1, where there is statistically significant evidence for a stable Cue 2 < Cue 1 effect (where Cue 2 = two cue precueing condition and Cue 1 = zero cue precueing condition) a stable 1 Element < 2 Element < 3 Element effect (where Element = number of elements per analogy term), a stable 1 Trans < 2 Trans < 3 Trans effect (where Trans = number of transformations between analogy terms), and significant interaction effects for Cue x Element, Cue x Trans, Element x Trans and Cue x Element x Trans, together with a comparatively long overall response latency for all conditions, cluster members are operating on a comparatively slow, comparatively stable strategy which is sensitive to the amount of precueing information provided, as well as variations in both the number of elements per analogy term and number of transformations between analogy terms. Furthermore, the Cue, Element and Trans factor related effects appear to be highly interactive.

The strategy being applied by cluster 2 is probably similar. The evidence of the same Cue 2 < Cue 1 effect observed in cluster 1, as well as the same 1 Element < 2

Element < 3 Element effect, the same 1 Trans < 2 Trans < 3 Trans effect, and similar significant interaction effects for Cue x Element, Cue x Trans, Element x Trans and Cue x Element x Trans, is all too similar in properties to the features identified in cluster 1. Thus it would appear that the noticeable and (significant) faster response times recorded for cluster 2 members, over all factorial conditions, constitute the major reason for the clustering algorithm's separating them from cluster 1 members. The same explanation cannot be offered for the clustering algorithm's separation of cluster 3 members from both cluster 1 and cluster 2 members.

The strategy being applied by cluster 3 members is somewhat different to those applied by cluster 1 and cluster 2 members. Most noticeable is the evidence of the same Cue 2 < Cue 1, 1 Element < 2 Element < 3 Element, and 1 Trans < 2 Trans < 3 Trans item complexity main effects observed in cluster 1 and cluster 2. However, in their very much slower response items over all factorial conditions cluster 3 members show no significant interaction effects for Cue x Element, Cue x Trans and Element x Trans. Moreover, and in contrast to the cluster 1 and cluster 2 strategies the Cue, Element and Trans factor related effects appear to be independent and additive in this strategy. In addition, the strategy ascribed to by cluster 3 members appears to be subject to progressive modification over time (Element and Trans related main and interaction effects). Perhaps here both the Element and Trans factor related effects indicate strategy refinement or learning rather than strategy alteration and may therefore be in keeping with the item familiarity effects reported by Sternberg (1985).

Thus the relative speeds between Nondegenerate analogy clusters 1 and 2 and cluster 3 appear to be accompanied by noticeable differences in information processing constraints that are not imposed by demand characteristics but by task demands.

That the effects identified for each analogy type are observed on the basis of statistical regularities over a comparatively large subject sample should serve to reinforce this appeal to information processing constraints and may perhaps even begin to offer insight into the influence of mental workload variations on geometric analogy task performance, an issue that will be reviewed in the section Componential Analysis and Mental Workload next in this chapter.

Componential Analysis and Mental Workload

Previously, in most instances of mental workload research, attention has been focused solely on the formation and evaluation of mathematical models that best define cognitive task performance under conditions of varying mental workload, rather than investigating underlying factors contributing to subjective variations in task performance. It has been the contention throughout this thesis that the latter form of investigation is dependent upon an accurate and robust model of task demands. Sternberg's (1977) componential theory of analogical reasoning proposes models of the nature, specific to analogy task performance, see the section Componential Models of Analogical Reasoning to Chapter 3 for a discussion of these models. However, despite its providing valuable insights into the nature of mental abilities, Sternberg's theory has until now been excluded from research designed to investigate the concept of mental workload. By replicating certain of the procedures employed by Sternberg (1977), in his Geometric Analogy Experiment, and incorporating these with certain other procedures, see the section "Componential Analysis" Revisited earlier in this chapter for a discussion thereof, the present study has attempted to investigate the extent to which findings from an apparently stable cognitive phenomenon, i.e., forced choice geometric analogy task solution, can offer insights into the influence of mental workload variations on cognitive task performance.

It will be recalled from the section Sternberg's Componential Theory of Analogical Reasoning in Chapter 3 that Sternberg (1977) tested several models representing different assumptions about serial versus parallel processing and exhaustive versus self-terminating processing in the element encoding and comparison components of Nondegenerate geometric analogy task solution. The model which accounted for the greatest portion of variance across different types of analogy items was one which encoding and inference of the transformations from the A term to the B term was serial and exhaustive, whereas mapping and application of the elements with respect to the C and D terms were serial and self-terminating, see Figure 3.6 in the section Componential Models of Analogical Reasoning in Chapter 3 for a flow chart and discussion of this model. However, it is important to note that the geometric analogies included in Sternberg's (1977) investigation were rather easy, and it could well be that the simple linear models (such as the one described above) that fit the response time data for simple analogy items do not necessarily apply for more complex times.

It is a contention of the present study that in any kind of cognitive process the probability of multi phasic, overlapping events cannot be ignored in favour of the appeal to simplicity of a neat linear, sequential model and furthermore, that it is naive to expect that information processing components operate in a discreet, mutually exclusive or additive way, as was the assumption in Sternberg's experimental work.

The design and procedure of the present study facilitated the verification of whether additivity of element and transformation processing holds for overall forced choice geometric analogy solution latency, across conditions of varying item complexity, as advocated by Sternberg (1977). Violations of additivity, depending on their severity and form, would suggest supplementary or alternative process assumptions for task performance.

From the sections Solution Strategy and the Experimental Task in Chapter 5 and Task Structure and Solution Strategy earlier in this chapter, it will be recalled that subjects introspective reports of task solution for each analogy type suggested a sequential information processing strategy, with information components operating in an additive way, thus supporting the experimental assumptions of Sternberg (1977). Furthermore, on the basis of subjective strategy reports it was concluded, for each experimental analogy type, that in terms of performance components adopted and order of component execution, changes in task complexity fail to elicit meaningful strategic variations on the part of subjects. However, in light of the outcome of the cluster analysis and subsequent analysis of variance procedures, it would appear that the abovementioned results and conclusions based on the analysis of subjects introspective reports together with Sternberg's (1977) proposals concerning the nature of element and transformation processing in forced choice geometric analogy task solution are reinterpretable.

It was noted earlier on in this discussion chapter that there were indications from the inspection of results partitioned by subjective reports and judgement codes that for each experimental analogy type there were non random effects attributable to strategy differences and item complexity associations, but that there was no apparent explanation as to whether these effects were meaningful, and if so, whether they could at all be attributed to the level of mental workload experienced by subjects during task performance. To overcome this impasse, a more rigorous and less prescriptive investigation of the pattern inherent within each of the four data matrices was undertaken, by means of examining the results of the cluster analysis procedures reported in Chapter 5.

Since the differences in rapidity between cluster response patterns for each of the four cluster solutions have been discounted as the sole basis for the solutions, it is assumed that each of the four solutions are directly related to the pattern or structure inherent in each of the four data matrices and are thus directly attributable to the effects of the independent variables in each of the factorial experimental designs.

The results of the cluster analysis and subsequent analysis of variance procedures strongly suggest the presence of two broad information processing strategy types for each of the experimental analogy types, i.e., a slower, comparatively unstable strategy type, slightly sensitive to variations in both the number of elements per analogy term and number of transformations between analogy terms (only variations in the number of elements per analogy term in the case of the Degenerate analogy items), mildly responsive to the amount of precueing information provided, and involving additivity of element and transformation processing (in the case of the Semidegenerate A:A::B:B, Semidegenerate A:B::A:B and Nondegenerate analogy items); and a significantly faster, more stable strategy type, highly sensitive to variations in both the number of elements per analogy term and number of transformations between analogy terms (only variations in the number of elements per analogy term in the case of the Degenerate analogy items), highly responsive to the amount of precueing information provided, and involving interaction of element and transformation processing (in the case of the Semidegenerate A:A::B:B; Semidegenerate A:B::A:B and Nondegenerate analogy items). Moreover, it is important to note that for each experimental analogy type, the former strategy type described above (which for present purposes will be referred to as Strategy I), was consistently employed by the minority of subjects; ranging from 5% (3/60) for the Degenerate analogy items, to 8,35% (5/60) for the Nondegenerate analogy items. Alternatively the latter strategy type (which for present purposes will be referred to as Strategy II was consistently employed by the vast majority of subjects.

At this juncture, it must be pointed out that in those cluster solutions comprising three clusters, i.e., the Semidegenerate A:A::B:B and Nondegenerate analogy cluster solutions, where differences in response time appeared to be the major reason for the clustering algorithm's separation of cluster 1 and cluster 2 members, the processing strategies employed in each of the clusters (i.e., clusters 1 and 2) have been categorised as a single broad strategy type, hence the abovementioned reference to "... two broad information processing strategy types for each experimental analogy type."

It will be recalled from the section Further Comments on Sternberg's Theory of Analogy in Chapter 3, that Pellegrino and Lyon (1979), while acknowledging the applicability of the simple linear models proposed by Sternberg (1977) to simple forced choice geometric analogy items, expressed doubt as to their applicability to more complex items. With this concern in mind, one possible explanation for the apparent dichotomy of strategy types for each experimental analogy type, given the characteristics of these strategy types, would be that Strategy I (which in terms of the nature of element and transformation processing corresponds closely with the Sternberg componential models) was employed for the solution of the least complex items within each analogy type, but as item complexity increased certain subjects (always the minority) were unable to employ a different working method (Strategy II), and continued with the application of Strategy I thereby resulting in a deterioration in task performance which is evidenced by the significantly higher solution times recorded by subjects employing this strategy type. In contrast certain other subjects (always the majority) were able to employ a different working method, i.e., Strategy II thereby maintaining a high level of task performance at increased levels of task complexity. It would therefore appear that increases in item complexity could in fact elicit meaningful strategic variations, on the part of certain subjects at least, in order to overcome associated increases in mental workload and maintain high standards of task performance.

If subjects do in fact employ the information processing components as indicated in the process models presented in the section Task Structure and Solution Strategy earlier in this chapter, and described as best defining task performance on each of the experimental analogy types (something which cannot be taken for granted for reasons stated previously in this chapter), and apply them according to either of the abovementioned information processing strategy types, it would seem reasonable to argue that while the simple linear models proposed by Sternberg (1977) define rather well subjects' task performance on simple forced choice geometric analogy items, they appear to be mere approximations of the apparently non linear behaviours employed in more complex forced choice geometric analogy problem solving situations.

Additive element and transformation processing may well be a viable strategy for simple forced choice geometric analogy task solution, but evidence assembled here suggests that it is not necessarily a "natural" (Jolicoeur, 1985) strategy for handling more complex forced choice geometric analogy items.

Under these circumstances the extent to which evidence of additivity of element and transformation processing (as advocated in Sternberg's theory) ought to be viewed as evidence for the investigation of the influence of mental workload variations of forced choice geometric analogy task performance is hardly compelling.

More pragmatically, a number of alternative features emerge from the data.

Firstly, response time data presented in Tables 5.1a - 5.1d clearly indicate that increasing the number of elements per analogy term increased solution time as predicted. This would apparently suggest that the element patterns comprising the terms of the experimental analogy items were decomposed serially, element by element as proposed by Sternberg (1977). The rate of processing elements was nearly constant (additive) within each transformation condition, but was found to vary as a function of the number of transformations between analogy terms, generally increasing in time per element with increases in the number of transformations. Similarly, transformations between terms appear to have been processed in a serial fashion as solution proceeded, additively wi'hin each number of elements condition, and increasing in time per transformation with increases in the number of elements. The response time data per cluster for each of the cluster solutions also suggest the presence of these response time effects.

Secondly, it will be recalled from the sections Stimulus Complexity and Task Performance and Clusters and Stimulus Properties earlier in this chapter that the major factor leading to increases in response latency (referring to Semidegenerate A:A::B:B, Semidegenerate A:B::A:B and Nondegenerate item solution) involves the number of transformations between analogy terms, rather than the number of elements per term. This issue will receive further attention later on in this section.

Thirdly, and of particular significance to the present research are the potential reasons why the data yielded by the cluster analysis and subsequent analysis of variance techniques indicated violations of simple additivity (for Semidegenerate A:A::B:B, Semidegenerate A:B::A:B and Nondegenerate item solution) under the combined effects of element and transformation processing. One potential explanation is that as item complexity increases, there begins to be a problem of mental workload that draws upon a limited capacity processing system. It is contended that each operation performed in decomposing element patterns and identifying transformations between the terms of an analogy yield units of information that need to be stored in working memory. As more partial information is accumulated and entered into memory, it may occur that the limits of such a processing system are reached. In such circumstances, both processing time and effort may have to be partially diverted to updating and maintaining the accumulated contents of working memory. This may be particularly true given that solution times carry over a range of seconds, thereby requiring information to be accessible to memory for more than a very brief duration.

Given these assumptions, the processes involved in element pattern decomposition and comparison and transformation analysis for simple forced choice geometric analogy items could be considered to be essentially additive, and memory load, which increases at an accelerating rate, produces the increasingly long solution times associated with increases in complexity. However, as both the number of elements per term and number of transformations between terms increase, item solution may require substantial external memory that is unavailable, thus creating a need for alternative processing strategies. This would amount to a shift in the proportion of total time that goes to the actual processing operations associated with element pattern decomposition and transformation analysis, as compared to the time for information management in the form of deliberate control and sequencing of the pieces of information to be sampled and tested. It would therefore not be unrealistic to assume that a certain amount of time sharing (McCormick and Sanders, 1982) takes place in complex forced choice geometric analogy task solution. This assumption is of great importance in the context of the present study since the notion of time sharing is a rejection of a rigid sequential strategy, such as that advocated by the simple linear models proposed by Sternberg (1977), in favour of a more integrated strategy involving interactive element and transformation processing.

It was noted earlier in this section that the response time data suggested that the major factor leading to increases in response latency (for Semidegenerate A:A::B:B, Semidegenerate A:B::A:B, and Nondegenerate item solution) involved the number of transformations between the terms of the item. The data reveal that as a function of item structure, there may be two different ways in which increases in transformational complexity lead to increases in response latency. In the two and three element items, where transformations are mapped onto separate elements, increases in response times can be justified in terms of an accumulation of independent representational events. However, for cases where there are multiple transformations of a single element, the data indicate the necessity for postulating an additional component that significantly contributes to increased response latency. The rationale for suggesting the inclusion of this additional component involves the amount of information that must be represented in working memory for any given item. A necessary assumption is that each transformation applied to the same or different elements requires at least one placekeeper in working memory (Kotovsky and Simon, 1973). Given this assumption it is possible to specify potential differences between items involving one-to-one versus many-to-one transformation to element mappings (for illustrative purposes task performance on a multiple element, multiple transformation Nondegenerate forced choice geometric analogy item shall be discussed).

An item with two separately transformed elements would probably require two memory placekeepers for inferring the relationship between the A and B analogy terms. However, an item with two transformations of the same element would apparently require at least two and possibly three memory placekeepers since the order or sequence of applying transformations may constitute a third component of transformation analysis. Another potential difference between the two item types is the requirement that individuals store and operate on intermediate internal representations during the application process from the C term to the answer options. All one-to-one mappings of transformations to elements would provide external sources for checking the results of applying separate transformations between the C term and the answer options. However, in the single element multiple transformation case, testing and memory would have to be internal for all but the final product of the application of several transformations. Thus, items with multiple transformations of a single element would probably require an additional memory placekeeper for storing the intermediate products of solution processes during the application process. The intermediate products that have to be stored, in addition to the other record keeping required, would further tax memory capacity and thereby result in increased response latency. It is important to note that the memory load explanation offered here is verified by empirical studies of performance on series extrapolation problems (e.g., Kotovsky and Simon, 1973; Holzman, Glazer and Pellegrino, 1976).

It would therefore appear that on the basis of the response time and cluster analysis data, forced choice geometric analogy solution is systematically related to both the element and transformation structure of individual items as originally hypothesised. The major determinant of response latency (on Semidegenerate A:A::B:B, Semidegenerate A:B::A:B and Nondegenerate items) was shown to be the transformational complexity of an item. Possibly the most interesting outcome of the latency and cluster analyses was the indication that working memory factors associated with the representation and management of item features provided the basis for nonadditive increases in response latency for forced choice geometric analogy task solution.

Fourthly, it would appear that performance on forced choice geometric analogy items requires a considerable amount of procedural knowledge and strategic expertise. Part of this expertise may include the ability to shift processing strategies in order to overcome the mental workload that arises when employing a strategy that is optimal for simple items but not for more complex items. If increased task demands can be dealt with only by a change in processing strategy, then the mechanism of strategy choice would be central to the subject's reaction to these demands (Norman and Bobrow, 1975).

Based on the present research evidence it appears that strategic flexibility served to enhance the subjects' level of proficiency on the experimental items, thereby reducing the mental effort required to meet task demands. Consequently the same actual demand would have imposed different operational workload dependent on the cognitive capabilities and strategic flexibility of the subject.

The present research findings suggest that the significantly slower response latencies of certain subjects for each of the factorial conditions under high task demands could have occurred as a natural function of normal decision making mechanisms, rather than through an actual deterioration in information processing capacities.

Lastly, it was noted in the section Procedure in Chapter 4 that experimental items were presented in either the zero or two cue precueing condition. The rationale for employing this procedure, as part of the present experimental design, was to facilitate the investigation of the influence of task uncertainty on forced choice geometric analogy task performance.

From the sections Stimulus Complexity and Task Performance and Clusters and Stimulus Properties earlier in this chapter, it will be recalled that the solution times recorded for experimental items presented in the two cue condition were consistently faster than those recorded for items presented in the zero cue condition. These findings are in accordance with those of Sternberg (1977).

A candidate explanation for these findings, in the context of the present research, is that whereas subjects would have apparently solved items presented in the zero cue condition by employing the information processing components indicated in the process models presented in the section Task Structure and Solution Strategy earlier in this chapter, and described as best defining task performance on each of the experimental analogy types, and applying them according to either Strategy I or Strategy II described earlier in this section, their solution of items presented in the two cue condition would have been subtly different. In the first part of item presentation subjects would have encoded the two terms presented, and inferred the relation between them. Having completed this, the second part of item presentation would have commenced. Here, subjects would have been presented with the entire analogy as it would have appeared had it been presented in the zero cue condition. Having encoded and inferred the relationship between the two terms in the first part of item presentation, solution of the analogy would have required merely a subset of the full set of information processing components (depending on the analogy types), identified in the section Task Structure and Solution Strategy earlier on in this chapter as best defining forced choice geometric analogy task performance, being applied according to either Strategy I and Strategy II. These assumptions would serve to explain the faster solution times recorded for items presented in the two cue condition. It would therefore not seem unrealistic to argue that subjects used the precueing information presented in the first part of item presentation to reduce the processing load encountered in the second part of item presentation.

Reducing task uncertainty by presenting subjects with precueing information in the first part of item presentation served to reduce the mental workload associated with item solution. This contention would appear to be supported by the consistently faster solution times recorded for items presented in the two cue condition.

Future mental workload research based on the findings yielded by, and using investigative and analytical techniques similar to those employed in the present study, may yield valuable information regarding the adaptive characteristics of cognitive task performance under conditions of varying workload, information which may serve to highlight important sources of individual and developmental differences in cognitive abilities.

These possibilities receive further attention in the section Prospects for Componential Analysis and Mental Workload Research next in this chapter.

Prospects for Componential Analysis and Mental Workload Research

So far this discussion chapter has concentrated upon interpretation of experimental data for a better understanding of the influence of mental workload variations on forced choice geometric analogy task performance, and it has culminated with the highlighting of certain issues that could serve to benefit future investigations into both the information processing components involved in cognitive task performance, as well as the implications of mental workload variation on cognitive task performance. This section attempts to set these issues within the wider context of componential analysis and mental workload research. It will be recalled from the protracted discussions in Chapters 3 and 4 that previous componential analysis and mental workload investigations have been restricted by a number of weaknesses.

It was noted in the section Conceptual and Methodological Issues in Chapter 4 that componential analysis research has suffered because of the repetitive use of small numbers of hypothesis sophisticated subjects and the reduction of subjects' solution strategies into (a) sequential model(s) on the basis of a priori assumptions of component execution.

Similarly, it was noted in the section The Concept of Mental Workload in Chapter 2 that the lack of consensus upon the definition of mental workload (Williges and Wierwille, 1979; Moray, 1982) could be attributed to the attempts by theorists to define workload as a unitary concept, having simple characteristics and effects.

It was argued that a unitary approach to mental workload and its measurement would result in methodological problems since the level of definition was often inappropriate for the level of research conducted. As a result, certain theorists have adhered to a number of untested and often invalid assumptions from which they propose methods of defining and evaluating mental workload (Teiger, 1978; Welford, 1978). Furthermore, in most instances of mental workload research attention has been devoted to the formulation and evaluation of mathematical models that "best" describe cognitive workload rather than investigating underlying factors contributing to subjective differences in task performance.

Since it is a theoretical construct, it was contended in Chapter 4, that mental workload might best be defined operationally, as this would facilitate dealing with the concept at various levels of detail so that the details of the experimental design would be adequately justified, thereby yielding logical and interrelated results and conclusions. For present purposes, an information processing approach was used as the basis for the construction of an operational definition of mental workload and its consequences, i.e., "the extent to which an individual is able to fulfil the mental task demands imposed by the task in which he/she is engaged".

It was noted further, in Chapter 4, that phase two of an operational definition involved the consideration of certain aspects in more detail. It was stated that in human information processing terms, performance and workload appeared to depend upon the interaction of four factors: the mental task demands (Bainbridge, 1978); the information processing capacities of the individual (Hacker et al., 1978); the strategies used to relate demands to cognitive capacities; and when a range of cognitive strategies is available, skill in choosing the most efficient (Norman and Bobrow, 1975). The present research has endeavoured to compensate for the shortcomings associated with previous componential analysis and mental workload investigations and was designed in such a way as to facilitate the investigation of the interaction of the abovementioned factors as they would apply to task performance on forced choice geometric analogy items.

This study has brought together evidence from the previously unrelated fields of componential analysis and mental workload research in order to investigate whether performance on an apparently stable cognitive phenomenon, i.e., the forced choice geometric analogy task, under conditions of varying complexity, can offer insights into the influence of mental workload on cognitive task performance.

The nature of [illegible] [illegible]ental design and procedure was such that [illegible] [illegible]dings which could have significant implica[illegible] [illegible]omponential analysis and mental workload resear[illegible] for the design of work involving cognitive t[illegible]

Present research findings have served to highlight the naivety displayed by cognitive components theorists such as Sternberg (1977), Pellegrino and Glaser (1980) and Pellegrino and Kail (1982), in their choosing to discount the probability of multi-phasic, overlapping events in favour of the appeal to simplicity of neat linear sequential models, and their acceptance that information processing components operate in a discreet, mutually exclusive or additive way. Models formulated on the basis of such theorising may appear to be superficially sufficient but will inevitably lack either credibility or generalisability, as has been evidenced by this study.

The present study has proposed several process models that, on the basis of the experimental data, would appear to best define task performance on Degenerate, Semidegenerate

(A:A::B:B) and Semidegenerate (A:B::A:B) forced choice geometric analogy items, in terms of information processing components adopted and order of component execution. It must however, be emphasised that these models are mere approximations of the very possibly non linear behaviours that individuals would employ in these problem solving situations. Perhaps these process models, together with the two broad information processing strategy types identified, i.e., Strategy I and Strategy II, could serve as a basis for future investigations into the information processing components involved in the solution of forced choice geometric analogy items of the types investigated here.

A significant outcome of this study was the indication that a certain amount of time sharing (McCormick and Sanders, 1982) occurs during complex forced choice geometric analogy task solution. This finding would appear to have important implications for future investigations into the information processing components involved in cognitive task performance, since the notion of time sharing is the rejection of a rigid sequential strategy to task solution, such as that advocated by the simple linear componential models proposed by Sternberg (1977), in favour of a more integrated strategy involving interactive element and transformation processing.

Data yielded from the cluster analysis and subsequent analysis of variance techniques revealed violations of simple additivity on forced choice geometric analogy items under the combined effects of element and transformation processing. Perhaps the most important outcome of this study was the indication that working memory factors associated with the representation and management of item features provided the basis for such non additive increases in response latency. Based on these findings, it would appear that future models of forced choice geometric analogy task solution in particular, and cognitive task solution in general, would have to incorporate additional control and/or memory management processes in order to explain performance on complex or difficult items.

Data yielded from subjects post hoc introspective reports of solution strategy, together with that yielded from the cluster analysis and subsequent analysis of variance techniques suggest that an individual's strategy and information processing constraints may be more flexibly applied to the forced choice geometric analogy task, particularly under conditions of increased complexity, than would be suggested by the simple linear componential models of analogical reasoning proposed by Sternberg (1977). This would imply that strategic flexibility on the part of an individual could serve to enhance his/her level of proficiency on the forced choice geometric analogy task in particular, and cognitive tasks in general, thereby resulting in a reduction of mental effort. Consequently, the amount of mental workload imposed by the same actual task demand, would appear to be a function of the cognitive capabilities and strategic flexibility of an individual. If this were the case, and increased task demands could only be dealt with by a change in solution strategy, the mechanism of strategy choice would be central to an individual's reactions to these demands and, as a result, should be of particular interest in the content of future componential analysis and mental workload research.

Future mental workload research based on the findings yielded by, and using investigative and analytical techniques similar to those employed in the present study, would do much to redress the disarray so evident in contemporary investigations in this field, and may produce valuable insights into the adaptive characteristics of cognitive task performance under conditions of varying workload. A development such as this could stand to benefit future research into the development of strategies for reducing the mental workload experienced by individuals having to perform complex cognitive tasks as part of their work, i.e., operators of automated systems.

The present research techniques of constraint free analysis (through the clustering procedure) and componential model and strategy formulation appear promising initial steps towards a more comprehensive understanding of the concept of mental workload and its strategic implications on cognitive task performance. As such the aims of the present research, as broadly set out under the section Hypothesis in Chapter 4, are generally supported.

Concluding Comments

The theme of research conducted and reported through this thesis is essentially simple, the research aims modest. The requirement posed was an enhanced understanding of the strategic implications of mental workload on cognitive task performance; the investigation of a large set of performance data using pre classificatory techniques of variance analysis, in search of meaningful inter and intraindividual strategic variations on the part of subjects performing a stable cognitive task under conditions of varying mental workload.

The background conceptual and theoretical issues reviewed in Part 1 of this thesis are, however, far reaching. The results yielded by the study have implications for each of the many strands of research drawn together in this review. Indeed, one of the central themes is the extent to which the same data, the same methodological flaws and the same erroneous assumptions are compounded into so many strands of contemporary cognitive science.

The research design adopted for this present research attempts to compensate for some of these flaws and areas of neglect. The design itself is not unusual, but the controls for experimental demand characteristics and the concern to avoid implicit strategy priming and response set creation are important steps to minimise further extraneous influences.

By contrast, the analysis is both novel and explanatory. The application of an appropriate cluster technique appears to offer a significant development in the exploration of information processing components in, and strategies employed for forced choice geometric analogy solution in particular, and cognitive task solution in general. Furthermore, the investigation of subjects' performance on a stable cognitive phenomenon, i.e., the forced choice geometric analogy task, under conditions of varying mental workload has provided valuable insights into the influence of mental workload on cognitive task performance.

By definition the sections Componential Analysis and Mental Workload and Prospects for Componential Analysis and Mental Workload Research are speculative, but speculation is an essential extension of the present research context.

Perhaps the major proposition to emerge from this thesis presentation is that unless theorists of cognitive ergonomics in particular, and cognitive science in general, choose to ignore approaches that lack conceptual and methodological credibility, such as those identified in the sections The Concept of Mental Workload in Chapter 2 and Conceptual and Methodological Issues in Chapter 4, in favour of more dynamic research programmes, progress in these fields is likely to be severely restricted.

CHAPTER 7

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