Relations as transformations:

Implications for analogical reasoning

Robert Leech

Denis Mareschal

Richard P. Cooper

School of Psychology

Birkbeck University of London

Address all correspondence to Robert Leech, School of Psychology, Birkbeck University of London Malet Street, WC1E 7HX, London, UK. <u>r.leech@bbk.ac.uk</u>. This work was supported by an ESRC (UK) studentship and European Commission grant NEST-29088 (ANALOGY).

<u>Abstract</u>

We present two experiments assessing whether the size of a transformation instantiating a relation between two states of the world (e.g., *shrinks*) is a performance factor affecting analogical reasoning. The first experiment finds evidence of transformation size as a significant factor in adolescent analogical problem solving while the second experiment finds a similar effect on adult analogical completion using a markedly different analogical completion paradigm. The results are interpreted as providing evidence for the more general framework that cognitive representations of relations are best understood as mental transformations.

Introduction

The question of what constitutes a relation is fundamental to much of cognition, especially for complex cognitive processes such as reasoning and problem solving (Holyoak, Gentner & Kokinov, 2001). A case in point is analogical reasoning which in large part involves judging the similarity between relations and structures of relations (Gentner, 1983). It follows that how relations are represented bears directly on theoretical accounts of analogy. The dominant theoretical approach to date is to treat relations as highly structured representations such as predicates with multiple arguments (e.g., Gentner, 1983), or as combinations of objects bound to actor or patient roles (e.g., Hummel & Holyoak, 1997).

In contrast, several authors now argue that mental representation of relations can best be understood as representations of a transformation between two states of the world (but see Larkey and Markman, 2005, for a critical discussion of this approach). For example, Hahn, Chater and Richardson (2003) have proposed a metric of similarity based on the number of steps it takes to transform one entity into another. Two entities are viewed as highly similar if a single operation can transform one into the other, and increasingly less dissimilar the more operations are needed. One consequence of Hahn et al's approach is that relational similarity, and so analogical reasoning, is conceived of in terms of transformations. In a similar vein, Thomas & Mareschal (1997) demonstrated how viewing similarity as transformation provides a parsimonious explanation of asymmetries in similarity judgements. Thomas & Mareschal (2001) applied their similarity as transformation approach to metaphor interpretation (closely related to analogical reasoning). In addition to general accounts of similarity as transformation, there are also extant, more specific mechanistic accounts of cognitive processes where relations are represented as transformation. For

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instance, Rogers and McClelland (2004) present a version of Rumelhart's (1993) connectionist model of semantic cognition wherein relations (e.g., IS, HAS) modulate the mappings between objects and attributes (e.g., bird HAS feathers). In such an account, a relation is actually instantiated as a transformation from one semantic entity (e.g., bird) to another (e.g., feathers).

The current work focuses on the size of transformations involved in simple analogies. While there has been substantial work showing that the surface similarity between two domains affects the likelihood that an analogy will be drawn (e.g., Gick & Holyoak, 1983; Novick, 1988; but see Blanchette & Dunbar, 2001; 2002, for other factors such as audience characteristics and goals on analogical reasoning as well as the important distinction between analogical retrieval and generation) there is little work on the effects of the relational similarity between two domains. One reason is that in the classical view of relations it is difficult to quantify the similarity between two different relations. However, if relations are viewed as mental representations of transformations, similar relations will have similar transformational effects. Thus two relations that change the state of the world in similar ways will be more similar than two transformations that change the state of the world in different ways. With regards to analogical completion, we propose that the size of a transformation should be one determinant of successful analogical reasoning involving that transformation. The central idea is that when there is a large enough transformation (i.e., relation), there is less overlap between the representations of the objects instantiating the transformation, thereby making that transformation less confusable with others - and consequent analogical reasoning more successful.

In the following two experiments we investigate whether transformation size is a performance factor in analogical reasoning, as might be expected if relations are transformations. The results of these experiments are especially informative because other major accounts of analogical reasoning and development (e.g. Gentner, 1983; Hummel & Holyoak, 1997; Hofstadter, 1995) do not conceive of relations as transformations, and make no obvious predictions about the impact of transformation size.

In what follows, transformation size is defined as the distance between two concepts within semantic similarity space. That is, a transformation is considered to be large when it involves two objects or states of objects that are very dissimilar and small when it involves object states that are similar. Experiment 1 establishes that transformation size is a factor in predicting the likelihood of analogical completion. Here, we employ Gick & Holyoak's (1983) reknowned analogical problem solving procedure. These experiments use a version of Dunker's radiation problem where participants are asked how best to use radiation to destroy a life-threatening tumor without damaging the patient. The desired answer involves using many low intensity rays converging on the tumor from different directions. Without prior knowledge or help high-school students were reported to provide the correct solution only 10% of the time. However, when participants were first given a story involving a different problem but with a structurally similar solution, the percentage of correct solutions to the radiation problem increased to approximately 30%. Transformation size is manipulated by modulating the size of the effect of the radiation from destroying the tumor to shrinking the tumor.

Experiment 2 replicates these results using a different form of analogy (the more classic item analogy) with multiple exemplars. The second experiment also includes measures of the size of semantic differences between items of a relations and rules out additional factors such as word frequency.

Experiment 1

In this variant of the classic Gick and Holyoak studies we investigate whether the size of a transformation affects success in analogical reasoning. Specifically, the experimental hypothesis is that participants will notice and apply an analogical solution to a problem more often when the transformation involved is larger (in terms of greater semantic difference between the transformed and untransformed states)

Method

Material and design

Participants were given a booklet containing: (1) a story about how to deal with a fire, and (2) a problem about how to treat a tumor. The stories and the problems were similar to those in Gick and Holyoak (1983).

There were three different task booklets corresponding to three different conditions (See Figure 1 and appendix 1). The *baseline condition* involved a story about putting out a fire and a problem asking how best to use lasers to destroy a tumor by burning. This condition most resembled the original Gick and Holyoak (1983) task. The *experimental condition* consisted of a story about controlling (rather than extinguishing) a fire and a problem about using lasers to shrink a tumor. Thus, the experimental condition involved a smaller transformation than the baseline condition (the idea being that a shrunken tumor is semantically and perceptually more similar to an intact tumor than is a destroyed tumor). The *baseline 2* condition was identical to the baseline condition except that the problem entailed lasers triggering a chemical reaction to destroy the tumor instead of simply burning it. Thus, while the mechanism

here is different from that in the baseline condition, the effect (outcome) is the same so the transformation (change from pre- to post-effect states) is the same.

[FIGURE 1]

The difference in transformation size between the baseline and experimental conditions leads to the prediction that, although the analogies are structurally identical, more participants will solve the problem appropriately in the baseline condition than in the experimental condition. The baseline 2 condition is intended to serve as a further control condition. Any difference in performance between the baseline and experimental conditions could arise as a consequence of the small changes of the wording in the stories and problems, irrespective of the size of transformations. However, the baseline 2 condition uses a different mechanism to achieve the same transformation as the baseline. Consequently, on the basis of the transformation size hypothesis, performance in the baseline 2 condition should not differ significantly from the baseline condition but should be significantly higher than performance in the experimental condition.

Participants

Because psychology undergraduates were likely to be highly familiar with the Gick and Holyoak experiments, we sought to recruit participants with no formal psychological training. To this end, 109 high-school students took part in the study. Each participant was randomly assigned into one of three groups with 34 participants in the baseline condition (mean age = 16.09 years), 42 in the experimental condition (mean age = 16.27 years) and 33 (mean age = 16.30 years) in the second baseline condition. Importantly, there are no significant developmental differences between analogical performance in this age group and the 18 to 20-years-olds typically used as participants in other studies (Goswami, 1991).

<u>Procedure</u>

Participants were tested in their classrooms. They were told that they were taking part in a study on reading comprehension and problem solving. The students were then randomly assigned a booklet corresponding to one of the three conditions. They were given 3 minutes to read the fire story and were told to memorise as much of it as possible. After this 3-minute period, the students were told to turn the page to the laser convergence problems. The students were then asked to read it and write down as many solutions as they could in 5 minutes. After 5 minutes participants were told that the fire story could help them solve the laser problem and asked to write down any additional solutions they could think of in a separate section of the booklet. Finally, the students were given a personal information questionnaire to fill in.

Results

Figure 2 shows the participants' responses in the three conditions. First, note that this study is not intended to test whether or not participants use analogy in problem solving, there is ample evidence from earlier versions of this experiment that they do (see Gick and Holyoak, 1980, 1983). However, it is reassuring that the percentage of respondents in the baseline condition that produce the correct solution without a hint (this is the condition that most closely resembles earlier versions of the experiment) is 35.3%, a value similar to that obtained by Gick and Holyoak (1983).

[FIGURE 2]

The results are clearest when the *solution* and *solution after a hint* responses are aggregated (see Figure 3). This indicates the proportion of participants within each group who successfully used the story to solve the problem, and so is an appropriate measure of analogical performance. Here, the proportion of correct responses in the baseline condition (82%) and the baseline 2 condition (76%) are comparable, whereas the proportion of responses in the experimental condition was substantially lower (57%).

[FIGURE 3]

A chi-square analysis was performed on the responses (solution or no solution) from the baseline condition and those from the experimental condition. This showed a significantly greater proportion of correct responses in the baseline condition as predicted, $\chi^2(1) = 5.53$, p (1-tailed¹) < 0.01. Similarly, there was a significantly higher proportion of correct responses in the baseline 2 condition than in the experimental condition ($\chi^2(1) = 2.83$, p (1-tailed) < 0.05). A final chi-square test compared the performance in both the baseline conditions. This showed no significant difference ($\chi^2(1) = 0.441$, p (2-tailed) > 0.50).

Discussion of Experiment 1

The data from this initial experiment revealed a significant difference in performance between the small transformation condition (the experimental condition) and the large transformation conditions (the two baseline conditions), suggesting that reducing the size of the transformation impairs performance on analogical transfer tasks. The comparison between the baseline and the baseline 2 conditions further suggests that this difference is the result of a change in the size of the transformations because the two conditions do not differ in their transformations, whereas the baseline 2 condition does differ significantly from the experimental condition. Thus, a change in the transformation mechanism, is not sufficient, on its own, to explain the difference in performance between large and small transformation conditions.

¹ A one-tailed χ^2 test was used here and in the following case as the experimental hypothesis was uni-directional. Such hypotheses can be formulated and tested for χ^2 when there is a single degree of freedom (Howell, 1997).

Experiment 2

The results of Experiment 1 are consistent with the prediction that analogies involving large transformation should be easier to solve than those involving small transformations. However, Experiment 1 involved only a single analogy and thus provides only limited evidence for the prediction. The result could conceivably have occurred because of some bias in the specific relations or objects involved in the analogy. Furthermore, Experiment 1 only used the analogical problem solving paradigm. Experiment 2 addresses this issue by investigating the same hypothesis as Experiment 1 with a:b::c:d analogical completion. As in Experiment 1, the hypothesis is that analogies involving large transformations.

Method

Participants

Fifty-five native English speaking first year psychology undergraduates took part in the experiment as part of their research methods course. The participants' were all enrolled in an adult education course and had a mean age of 32.27 years. They were of diverse ethnic background and SES. Fourteen of the participants were male.

Materials and design

This experiment used the familiar *a*:*b*::*c*:*d* analogy format, regularly used in academic achievement tests. Participants were presented with 14 different analogies (see appendix 2). Each analogy had two forms: one involving a larger transformation and the other involving a smaller transformation as assessed by the experimenters

(Figure 4). Each participant received seven large transformation analogies and seven small transformation analogies.

[FIGURE 4]

In designing the analogies, the relations between the *a* and *b* terms and the *c* and *d* terms were chosen because they vary along some degree of intensity. For example, *damp* is a less intense instantiation of the relation *wetter* than *drenched*. To enable the classification of the transformation as high or low, it was important that the *a:b* and *c:d* terms in the experiment involve highly similar transformations. Thus, for example, the *a* and *b* terms *damp* and *drenched*, instantiated the relation *wetter*, while the *c* and *d* terms *drizzle* and *downpour*, provided an example of the similar "amount-of-water" relation *rainier*.

Participants were presented with the a:b::c terms of each analogy before being asked to select a d term from one of four options. These were composed of the analogically appropriate response and 3 distractors. The distractors were the same for both large and small transformation conditions of each analogy. This ensured that the only difference between large and small conditions of a particular analogy was in the b and d terms. So, any difference in performance would have to be the result of the difference between the large and small transformation conditions.

The distractors were chosen such that each analogy had a distractor that was: i) an associative match of the *c:d* relation (e.g. umbrella), ii) an additional example consistent with the *a:b* relation (e.g., moist), and iii) a term consistent with a different, but similar relation to the *c:d* relation (e.g., storm). (See *appendix 2*.)

<u>Procedure</u>

Participants were tested using a web browser on computer terminals. The experiment interface was written in html and javascript with additional cgi scripts

written in Perl. There were four blocks of experiments across two evening sessions with a maximum 24 students participating in each block. Participants were instructed to try to answer as quickly and accurately as they could.

Participants were first presented with three practice trials in which they were given an analogy to complete and provided with feedback. If participants wanted more practice, they were given the option of attempting an additional two trials. In the test phase, participants were prompted to answer all 14 analogies without feedback. The presentation order of the analogies was randomised, as was the order of the distractors and the choice of which seven analogies involved large transformations and which seven involved small transformations.

After the 14 test analogies had been presented, participants were asked to rate the semantic difference (a measure of transformation size) associated with each pair of terms in the analogies they had attempted to solve. Here, the participants were instructed to consider each analogy and decide how semantically similar the *a* term was to the *b* term, or how semantically similar the *c* term was to the *d* term. The reasoning here was that the greater the transformation the lower the similarity rating should be. The *a* or the *c* term was presented on the screen alongside the *b* or *d* term. Participants were asked to give their ratings on a seven point scale, with 1 indicating that the two terms had very different meanings and 7 indicating that they had very similar meanings. This procedure was repeated with each analogy for both the *a:b* and *c:d* relations. Thus, each participant provided 28 ratings in total. The presentation order of the ratings was randomised.

Results

The mean proportion of analogically appropriate responses per participant (irrespective of the size of transformation) was 0.66 (s.d. = 0.16). A t-test revealed

that participants were responding significantly above the chance level of 0.25: (t (54) = 19.40, p < 0.0001).

We begin by considering whether our experimental manipulation did in fact modulate the semantic content of the comparisons in line with small and large transformations. The ratings out of 7 for both pairs of comparisons in the analogy (e.g., damp vs. drenched, and drizzle vs. down-pour) were added together giving a composite transformation similarity score for each complete analogy problem, ranging between 2 and 14. Table 1 shows the difference between ratings for the small and the large transformation conditions by analogy (i.e., small transformation condition rating minus the large transformation condition rating: 9.0 - 6.6 = 2.4, see Analogy 8). Thirteen of the fourteen rating differences are positive indicating that in general participants rated the semantic difference between the terms as larger in the large transformation condition than in the small transformation condition (p < 0.001)by a sign test).

[TABLE 1]

Moreover, independent sample t-tests reveal that the semantic similarity ratings for all analogies were significantly larger (p < 0.05) in the large transformation size condition than the small condition, except analogies 6 and 14 where there is no significant difference (for analogy 6: t (54) = -0.80, p = 0.43; for analogy 14: t (54) = 0.14, p = 0.89). Consequently the assignment of the analogies in 6 and 14 into large or small transformations may not be justified. Therefore, performance on these analogies was not included in the subsequent analyses.

The mean proportion of correct responses in the large and the small transformation conditions were 0.761 (s.d. = 0.219) and 0.589 (s.d. = 0.178) respectively. As predicted, more analogies were solved correctly in the large

condition than the small condition. A paired-samples t-test shows that this difference was strongly significant (t(54) = -5.30, p < 0.0001).

It is possible that the observed strongly significant effect does not, in fact, result from differences in transformation size, but is actually a consequence of differences in word frequency or semantic association between the terms in the analogies. However, the log word frequencies² of the *b* and *d* terms (i.e., the only terms that varied between the two conditions) of the large and small transformation conditions did not differ marginally or significantly with parametric and non-parametric tests. Similarly, Latent Semantic Analysis³ (Landauer & Dumais, 1997) of the semantic associations between the *a* and *d*, and *b* and *c* terms of the analogies and all of the distractors (i.e., all the possible semantic association differences between the two conditions. In sum, the difference between the large and small transformation size conditions does not appear to be the indirect consequence of differences in word frequency or semantic similarity with other terms.

Discussion of Experiment 2

The strongly significant within-subject t-test indicates poorer analogical performance in the small transformation condition than the large transformation condition. This effect cannot be explained away as a consequence of systematic differences in word frequency. Since the only differences between the conditions were the b and d terms of the analogies (the a and c terms and the distractors were constant

² Word frequency was taken from the British National Corpus, a balanced corpus of over 100,000,000 spoken and written words representing a balanced wide range of British English.

³ Latent Semantic Analysis is an objective measurement of semantic relatedness extracted from the text of a given corpus.

to both conditions), the observed effects are due to the difference between these terms.

General Discussion

The results from Experiments 1 and 2 are both consistent with analogical reasoning using a metric of similarity based on transformation similarity. The two experiments differed substantially in the types of analogy used, the relations in the analogies, the objects and the participants. As such the combined results provide strong evidence that transformation size is a performance factor in analogical reasoning. These results are given greater credence by the use of (1) two different analogy procedures, and (2) two different populations (adolescents and adults). They suggest a systematic and consistent effect of transformation size on analogical reasoning.

Importantly, the results from Experiments 1 and 2 differentiate between accounts of analogical reasoning. Many accounts (e.g., Structure-Mapping Theory) postulate explicit initial representations of relations. In these accounts, it is hard to see how the size of a relation (transformation) could be incorporated into the model and affect performance in analogical reasoning. Consequently, the experimental results set out in this chapter provide a challenge for many traditional accounts of analogical reasoning. We contend instead that the evidence presented above is better accounted for by the Analogy as Relational Priming model (Leech et al, 2003; Leech et al, submitted). The ARP account suggests that analogy arises from the interaction of a constellation of basic memory processes (such as priming and pattern completion). One of the central tenets of ARP is that relations are represented as transformations

between states. As such, transformation size is naturally accounted for as a constraint on analogical reasoning.

One important issue that affects the generality of the results presented here is whether transformation size is a factor in all analogical reasoning analogies (and by extension whether all relations are best conceived of as transformations or not) or if it is involved in only a subset of these. Although, the two experiments are substantially different, they both use relations which can vary along a dimension of intensity. This allows them to be thought of easily as transformations of differing size. For other analogies it is initially less clear how the underlying relations can be thought of in terms of transformation size (e.g., "bullet is to gun as arrow is to bow"). However, although less transparent this does not mean that other relations are not transformations. For example, a much more abstract relation such as IS can be understood as the transformation from one representation (e.g., *Robin*) to another representation (e.g., *Bird*). In this sense, there is potentially no limit to which relations can be conceived of as transformations, and so transformation size may be a performance factor in many analogies and, in a similar vein, across a range of cognitive processes.

Finally, one possible limitation of the present work is that it only treats analogies involving binary relations. This appears to ignore the fact that many relations involve more than two terms, for instance the ternary relation: GIVES(*John*, *Mary*, *book*). Predicate and other similarly structured representational accounts naturally explain such n-ary relations since they involve nothing more than adding an extra argument to the predicate (e.g., P(a,b) is a binary relation whereas P(a,b,c) is a ternary relation). However, one simple way, following event semantics (Davidson, 1967), to generalise the account to analogies involving n-ary relations would be to decompose an n-ary relation in terms of multiple binary relations around an event: i.e., GIVER(*event, John*), GIVEE(*event, Mary*) and GIVEN(*event, book*). As such transformation size would affect the salience of each binary relation independently. Another possibility is that transformations between components of the relation involve a more complex interrelationship. For instance, some possibly weighted combination of the semantic differences between *John, Mary* and *book* may conjointly contribute to the overall salience of the ternary form of the relation GIVES in any subsequent analogical reasoning. Thus, there is no a priori reason for thinking that transformational accounts of relations could not also account for ternary and greater relations.

In summary, evidence form two different methods and with two different populations suggests that transformation size is a significant performance factor in analogical completion. This finding is consistent with accounts of similarity as transformations.

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	Difference in means	Standard error of dif
Analogy 1	2.23	0.82
Analogy 2	1.76	0.80
Analogy 3	2.70	0.48
Analogy 4	1.78	0.75
Analogy 5	1.68	0.71
Analogy 6	-0.42	0.53
Analogy 7	3.36	0.85
Analogy 8	2.40	0.75
Analogy 9	2.18	0.59
Analogy 10	1.32	0.56
Analogy 11	5.18	0.52
Analogy 12	5.87	0.75
Analogy 13	4.08	0.74
Analogy 14	0.10	0.75
Overall (mean)	2.44	

Figures and Tables

<u>*Table 1:*</u> Differences in participants' ratings between items in the small and large transformation size conditions for each analogy.



Figure 1: *The three conditions in the experiment and how they relate to each other.*



<u>Figure 2</u>. The percentage of participants who provided the appropriate solution either immediately after presentation of the story, after being given a hint, or who failed to provide the solution.



Figure 3: *The percentage of participants who provided the appropriate solution.*



Figure 4: An example of large and small transformation analogies.

Appendix 1

Baseline 1 condition: Problem

Suppose you are a doctor faced with a patient who has a tumour in their prostate.

There is a laser which can be used to destroy the tumour alleviating the symptoms. If the lasers reach the tumour all at once at a sufficient intensity then the tumour will be destroyed. Unfortunately, at this intensity the healthy tissue that the lasers pass through will also be destroyed. At lower intensities the lasers are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to destroy the tumour with the lasers, and at the same time avoid damaging healthy tissue?

Experimental condition: Problem

Suppose you are a doctor faced with a patient who has a tumour in their prostate.

There is a laser which can be used to shrink the tumour alleviating the symptoms. If the lasers reach the tumour all at once at a sufficient intensity then the tumour will be adequately shrunk. Unfortunately, at this intensity the healthy tissue that the lasers pass through will also be destroyed. At lower intensities the lasers are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to reduce the size of the tumour with the lasers, and at the same time avoid damaging healthy tissue?

Baseline 2 condition: Problem

Suppose you are a doctor faced with a patient who has a tumour in their prostate.

There is a laser which can be used to treat the tumour alleviating the symptoms. If the lasers reach the tumour all at once at a sufficient intensity then a chemical reaction will be triggered which will destroy the tumour. Unfortunately, at this intensity the healthy tissue that the lasers pass through will also be destroyed. At lower intensities the lasers are harmless to healthy tissue, but they will not affect the tumour either. What type of procedure might be used to destroy the tumour with the lasers, and at the same time avoid damaging healthy tissue?

Baseline conditions: Story

One hot summer night a fire broke out in an area of ancient woodland. Archaeologists were working in the woodland excavating a very important Iron Age village. If the fire wasn't put out it would spread to a nearby town and devastate much of the local countryside as well as destroy the ancient site. Luckily the site was very near a lake, so there was plenty of water available. If a large volume of water could hit the fire at the same time, it would be extinguished. However, the firemen were under instructions to save as much as possible of the ancient site and if they used their most powerful hosepipe they would destroy the historically important ruins and the ancient woodland forever. The situation looked hopeless.

Just then, however, the fire chief arrived and started to organise everybody. He stationed the firemen in a circle around the fire with all the available small hoses. When everyone was ready the hoses were opened up and the water was directed onto the fire from all directions. In this way a huge amount of water struck the fire at the same time without causing too much damage to the excavations. The Iron Age village and the ancient woodland were saved and the archaeologists could return to work in a couple of days.

Experimental condition: Story

One hot summer night a fire broke out in an area of ancient woodland. Archaeologists were working in the woodland excavating a very important Iron Age village. If the fire wasn't controlled it would spread to a nearby town and devastate much of the local countryside as well as destroy the ancient site. Luckily the site was very near a lake, so there was plenty of water available. If a large volume of water could hit the fire at the same time, it would be dampened down and it wouldn't devastate the site or spread. However, the firemen were under instructions to save as much as possible of the ancient site and if they used their most powerful hosepipe they would destroy the historically important ruins and the ancient woodland forever. The situation looked hopeless.

Just then, however, the fire chief arrived and started to organise everybody. He stationed the firemen in a circle around the fire with all the available small hoses. When everyone was ready the hoses were opened up and the water was directed onto the fire from all directions. In this way a huge amount of water struck the fire at the same time without causing too much damage to the excavations. The fire was prevented from spreading any further or doing any further damage to the ancient woodland or the Iron Age village, and the next morning heavy rain extinguished the remaining flames.

Appendix 2

PRACTICE ANALOGIES					
	CORRECT	DISTRACTORS			
Bullet is to Gun as Arrow is to	Bow	Direction	Firearm	Archer	
Plane is to Air as Submarine is to	Water	Flight	Navy	Torpedo	
Right is to Wrong as Good is to	Bad	Mistaken	Morality	Decent	
Man is to Child as Oak is to	Acorn	Tree	Leaf	Teenager	
Nose is to Smelling as Eye is to	Seeing	Glasses	Stink	Listening	

Practice analogies and response choices.

LARGE TRANSFORMATIONS	CORRECT		DISTRACTORS	
1 Ocean is to Fountain as Desert is to	Sandbox	Oasis	Water	Parched
2 House is to City as Star is to	Galaxy	Sun	Celebrity	Dwelling
3 Scintillating is to Dull as Happy is to	Miserable	Enthusiastic	Smile	Bored
4 Boiling is to Warm as Chilly is to	Freezing	Scorching	Pepper	Winter
5 Tractor is to Aeroplane as Walk is to	Sprint	Sit	Bicycle	Trainers
6 Valley is to Mountain as Mine is to	Tower	Canyon	Coal	Bury
7 Snack is to Feast as Peckish is to	Starving	Thirsty	Food	Bite
8 Damp is to Drenched as Drizzle is to	Downpour	Moist	Umbrella	Storm
9 Asleep is to Wide Awake as Calm is to	Frantic	Crying	Tranquiliser	Napping
10 Noisy is to Deafening as Quiet is to	Silent	Ear-Splitting	Peaceful	Headphones
11 Bigoted is to Fair as Obsessed is to	Indifferent	Prejudiced	Passionate	Fanatic
12 Genius is to Stupid as Crazy is to	Sane	Mastermind	Straightjacket	Bad
13 Guzzle is to Sip as Cascade is to	Stream	Drink	Chemical Reaction	Rocks
14 Bright is to Dark as Midday is to	Midnight	Dazzling	Lunchtime	Sun

The test analogies in the Large transformation condition and response choices.

SMALL TRANSFORMATIONS	CORRECT		DISTRACTO	RS
1 Ocean is to Sea as Desert is to	Beach	Oasis	Water	Parched
2 House is to Village as Star is to	Constellation	Sun	Celebrity	Dwelling
3 Scintillating is to Unremarkable as Happy is				
to	Fine	Enthusiastic	Smile	Bored
4 Boiling is to Hot as Chilly is to	Cold	Scorching	Pepper	Winter
5 Tractor is to Motorcar as Walk is to	Jog	Sit	Bicycle	Trainers
6 Valley is to Plain as Mine is to	Road	Canyon	Coal	Bury
7 Snack is to Meal as Peckish is to	Hungry	Thirsty	Food	Bite
8 Damp is to Soggy as Drizzle is to	Shower	Moist	Umbrella	Storm
9 Asleep is to Tired as Calm is to	Restless	Crying	Tranquiliser	Napping
10 Noisy is to Loud as Quiet is to	Hushed	Ear-Splitting	Peaceful	Headphones
11 Bigoted is to Narrow-Minded as Obsessed				
is to	Concerned	Prejudiced	Passionate	Fanatic
12 Genius is to Smart as Crazy is to	Eccentric	Mastermind	Straightjacket	Bad
			Chemical	
13 Guzzle is to Swig as Cascade is to	Torrent	Drink	Reaction	Rocks
14 Bright is to Dim as Midday is to	Dusk	Dazzling	Lunchtime	Sun

The test analogies in the Small transformation condition and response choices.