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The Structure and Function of Spontaneous Analogising in Domain-Based
Problem Solving

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Abstract

Laboratory-based studies of problem solving suggest that transfer of solution principles from an analogue to a target arises only minimally without the presence of directive hints. Recently, however, real-world studies indicate that experts frequently and spontaneously use analogies in domain-based problem solving. There is also some evidence that in certain circumstances domain novices can draw analogies designed to illustrate arguments. It is less clear, however, whether domain novices can invoke analogies in the sophisticated manner of experts to enable them to progress problem solving. In the current study groups of novices and experts tackled large-scale management problems. Spontaneous analogising was observed in both conditions, with no marked differences between expertise levels in the frequency, structure or function of analogising. On average four analogies were generated by groups per hour, with significantly more relational mappings between analogue and target being produced than superficial object-and-attribute mappings. Analogising served two different purposes: problem solving (dominated by relational mappings), and illustration (which for novices was dominated by object-and-attribute mappings). Overall, our novices showed a sophistication in domain-based analogical reasoning that is usually only observed with experts, in addition to a sensitivity to the pragmatics of analogy use.

The Structure and Function of Spontaneous Analogising in Domain-Based Problem Solving

Theorists have traditionally viewed analogical reasoning as a core element of intelligent thought (Raven, 1938; Sternberg, 1977), and recent evidence suggests that it may play a central role in the retrieval of information from long-term memory (e.g., Schank, 1999), in domain-based skill acquisition (Anderson, 1983), and in creative problem solving (e.g., Holyoak & Thagard, 1995). It is this latter area of activity that forms the focus of the present research. In problem-solving contexts analogical reasoning is typically viewed as entailing the use of “base” information from a previous problem-solving episode to facilitate attempts at solving a current “target” problem. It is noteworthy, however, that the postulated importance of analogising in problem solving stands in sharp contrast to many findings concerning the nature and extent of analogical problem solving in laboratory studies. For example, pioneering experiments by Gick and Holyoak (1980, 1983) demonstrated that providing participants with a base analogue prior to them tackling a superficially different but conceptually similar target promoted only a modest increase in solution rates (i.e., to levels of 20-30%) relative to a control condition where no analogue had been presented. It was only in conditions where explicit *hints* were provided about the relevance of the base information to the target problem that high levels of facilitated performance arose (see also Anoli, Antonietti, Crisafulli, & Cantoia, 2001).

Other studies have clarified that the transfer of an analogous solution in the absence of directive hints is also not greatly elevated by manipulations

such as: (a) giving participants a static diagrammatic representation of the underlying solution-structure associated with the base problem (e.g., Gick & Holyoak, 1983; Pedone, Hummel, & Holyoak, 2001); (b) providing problem solvers with an abstract verbal statement summarising the underlying conceptual nature of the base problem and its solution (e.g., Gick & Holyoak, 1983); or (c) re-presenting the base information to the participant whilst they are processing the target (Anoli et al., 2001; Gick & Holyoak, 1980). Taken together, this evidence appears to support the contention that whilst people may be good at utilising prior problem and solution information when they are directed to do so, they may be rather limited in their capacity to detect such analogous information in the first place.

Evidence for Spontaneous Analogising

Some studies, however, have produced more striking evidence for the spontaneous use of analogies by problem solvers. For example, Pedone et al. (2001, Experiments 3 and 4) demonstrated the effectiveness of *animated* displays of base analogues for spontaneous transfer. In addition, Holyoak and Koh (1987) and Keane (1987) have shown that people do notice and apply prior analogues when there are high levels of *surface similarity* in the information content of the base and target, in addition to underlying conceptual similarity. This latter situation arguably relates more closely to much real-world problem solving, where “within-domain” analogies involving close variants of a target problem are likely to be available. For example, Ball, Ormerod, and Morley (2004) illustrate the role of within-domain analogising in professional design practice with reference to an industrial designer who,

when tackling an information-display problem, was readily able to bring to mind previous design experience relating to other displays that he had worked on in the past.

At a theoretical level, Sweller (1980) has argued that much of the time there is, in fact, a strong correlation between the *surface features* of problems and their underlying *abstract solution structures*. Therefore, relying on surface features to access what might be a relevant base problem may be a valuable heuristic (cf. Blessing & Ross, 1996), and one that the human cognitive system may well have evolved to operate. As a heuristic, however, it is likely to be far from foolproof, and may, on occasions, lead to attempts to map between base and target problems that, whilst appearing to be superficially similar at a surface level, in fact have no underlying conceptual association in terms of solution structures (e.g., see Novick, 1988, for relevant evidence).

Apart from the role of surface similarity in driving spontaneous analogical reasoning, other research has provided evidence for unprompted analogising when *multiple* analogues are presented prior to the target problem -- even when such analogues share few surface similarities to the target (see Gick & Holyoak, 1983; Catrombone, & Holyoak, 1989). This line of research is particularly interesting as it suggests that a primary mechanism underpinning the development of domain-based expertise may well be analogical reasoning. The essential claim of theorists taking this position (e.g., Anderson, 1983; Blessing & Ross, 1996; Gick & Holyoak, 1983; Schank, 1999) is that repeated exposure to within-domain problems serves to promote the induction of generalised *knowledge schemas*. Such schemas embody an

abstract conceptual understanding of the underlying structure of problems, and serve to enable the recognition of problem “types”; they also embody a procedural understanding of how best to solve problems of that particular type.

Analogical Problem Solving in Real-World Contexts

Recently, spontaneous analogical problem solving has started to be investigated in applied contexts. This research has particularly focused on the behaviour of experts. For example, Marchant, Robinson, Anderson, and Schadewald (1993) investigated the use of analogies in the interpretation of tax statutes in graduate students and professional lawyers. They found that both groups demonstrated high rates of transfer from domain-based structural analogues. Likewise, Clement (1988) found that science experts frequently evoked analogies when attempting to explain a concept. Most recently, Dunbar and colleagues (e.g., Dunbar, 2001; Dunbar & Blanchette, 2001) have documented the use of analogy by immunologists and molecular biologists, finding that structural analogising was prevalent in a range of scientific activities, such as formulating hypotheses, designing and modifying experiments, and giving explanations to other scientists. Dunbar (2001) was also able to determine the function of the analogies in his observations. When isolated, unexpected results occurred the scientists drew analogies to similar experiments, what Dunbar (2001) calls “local” analogies. However, when a series of unexpected results occurred the scientists drew more distant analogies to the function of similar components in other organisms. Thus the

type of analogical mapping appears to differ depending on the purpose for which it is drawn.

In sum, it appears that experts in applied settings are able spontaneously to draw analogies between base and target problems. This is consistent with the widely held view that key differences between experts and novices reflect different levels of information encoding. Experts are able to encode information at a deeper, structural level, whilst novices generally encode information at a more surface or superficial level (Chi, Feltovich, & Glaser, 1981; Klein, 1999; Novick, 1988). In this way, experts solving domain-based problems are able to exploit the underlying relational structure of information much better than novices, who generally rely more on the superficial features of problem situations (Chi et al., 1981; Klein, 1998; Novick, 1988). This account of expert problem solving is also consistent with the findings of Thompson, Gentner, and Loewenstein (2000), who observed that unless management students were actively encouraged to compare base analogues in order to draw out their structural relations, their rate of transfer of an underlying concept remained low.

In contrast to Thompson et al.'s (2000) findings, however, there is some evidence that novices, like experts, can readily make use of structural analogies without being directly encouraged to create such structural mappings. For example, Blanchette and Dunbar (2000) asked novices to engage in political analysis and generate base analogues to explain a target concept to others. It was found that these novices were readily able to draw

structural inferences from the target domain to semantically distant source domains that also possessed little superficial similarity to the target problem.

Overall, then, the extent to which domain novices are able to draw on analogies when tackling problems remains unclear, with the few existing studies showing some inconsistent findings that may well relate to methodological aspects of the research – a point that is argued persuasively by Blanchette & Dunbar, 2000. For example, their own study that reveals good levels of structural analogising in novices adopts what they refer to as a *production paradigm*, whereby participants are given a target problem and asked to generate a source analogue. This contrasts with the lower levels of novice analogising in Thompson et al.'s (2000) study and most traditional laboratory-based research, which adopt what they term a *reception paradigm*, whereby participants have to detect a relation between source and target problems that are presented.

Our present study, then, was designed as an attempt to address further the issue of spontaneous analogising in real-world novice and expert problem solving. Our chosen domain was management science, which allows practitioners to draw widely on multiple sources of stored knowledge to affect solutions to problems. Our study investigated both management novices (undergraduates) and management experts (postdoctoral academics) conducting group-based analyses of a presented “business case” (Easton, 1992). Participants worked in teams and were required to specify the problems and opportunities inherent in the case, and to produce a set of solutions that might optimise the success of the business described in the case. The task may

be described as ill-defined (Van Lehn, 1989) and, in some respects, undefined, as multiple solution possibilities exist, and there is no objective metric for judging attainment of an optimal solution.

Our study involved comparisons between the frequency and structural complexity of analogising in expert and novice management practitioners. In light of observations concerning the differing functions of analogies in real-world situations, we were also alert to the possibility that management contexts might similarly be associated with analogy use aimed at attaining different practical goals. To achieve our aims, analogies first needed to be identified in the transcribed discussions of collaborating participants, and then had to be categorised using a pre-defined coding scheme. The identification of analogies was based on a technique developed by Clement (1988), and will be considered in more detail in the method section below. The coding of analogies derived from a scheme developed by Gentner (1983) for classifying the syntactic elements of information that are mapped between base and target domains (see also Falkenhainer, Forbus, & Gentner, 1989), and is described below.

The Structure of Analogies

Like Gentner, we also view domains as being *systems* of objects, object-attributes and relations between objects. As such, domain knowledge can be understood as comprising propositional networks of nodes and predicates (e.g., Rumelhart & Ortony, 1977; Schank & Abelson, 1977), where nodes represent concepts, and where predicates are applied to nodes to express propositions about concepts. One critical syntactic distinction among predicate

types advanced by Gentner (1983) is that between *object-attributes* versus *relations*. This distinction can readily be made explicit in the predicate structure. Thus object-attributes are simply predicates that take on a single argument of the form, PREDICATE (argument₁), as in the following example that describes the colour of an object or entity¹: BROWN (Hercules-the-dog). In contrast, relations are predicates that take on two or more arguments of the form PREDICATE (argument₁, argument₂...argument_n), as in the following example: CHASE (Hercules-the-dog, Fifi-the-dog).

Under this distinction between attributes and relations, base-to-target mappings could arise at: (a) just the level of attributes and associated objects; (b) just the level of relations; or (c) a mix of both levels. Gentner (1983), however, argues that type-a and type-c mappings are best viewed as being *mere appearance matches* and *literal similarities*, respectively, rather than examples of “pure” analogies (see also Gentner & Markman, 1997). She reserves the term “analogy” for situations where there are few or no object-and-attribute mappings between base and target domains relative to many relational mappings, as in type-b. Our own research on spontaneous analogising in real-world practice (Ball et al., 2004; Bearman, 2004) suggests that few cases of analogising reach the status of being exclusively relational in nature. Thus our coding scheme simply aimed to dichotomise instances of analogising that were either purely object-and-attribute level mappings (i.e., mere appearance matches) versus those that involved relational mappings (irrespective of whether or not object-and-attribute mappings were also occurring). Henceforth we refer to the former category of analogising as

object-and-attribute analogies, and the second category as *relational analogies*.

A second syntactic distinction advanced by Gentner (1983) is that between *first-order* predicates (that take objects as arguments) and *higher-order* predicates (that take propositions as arguments). For example, CHASE (Hercules-the-dog, Fifi-the-dog) and RUN-AWAY-FROM (Fifi-the-dog, Fifi's-owner) are both first-order predicates, whereas CAUSE [CHASE (Hercules-the-dog, Fifi-the-dog), RUNS-AWAY-FROM (Fifi-the-dog, Fifi's-owner)] is a second-order predicate². It is clear that the *order* of a mapping has a very close association to the *level* of the entities that are mapped (as described previously) with the pure object-and-attribute mappings discussed above being lower-order predicate mappings in contrast to mappings of relations and systems of relations, which encompass higher-order predicate mappings. This observation allowed us to finesse the distinction between mapping level and mapping order for the purpose of our primary analysis of analogy structure. Thus, we simply utilised the single coding scheme already described (i.e., identifying object-and-attribute analogies vs. relational analogies) in order to capture salient aspects of the structure of analogising arising in the problem solving of our novice and expert participants. The fact that our relational category encompassed both first-order predicate mappings as well as higher-order predicate mappings seems warranted on theoretical grounds, given that such analogies are clearly distinct in a syntactically significant way from pure object-and-attribute analogies that simply reflect mere appearance matches in Gentner's (1983) terminology.

The Function of the Analogies

The structure-oriented coding scheme that we have just outlined was unable to address issues relating to the *purpose* or *goal* for which analogies might be drawn in our study. The pragmatic analysis of analogical transfer was pioneered by Holyoak (1985), and since this time pragmatics have been found to constrain how ambiguity is resolved (e.g., Spellman & Holyoak, 1996) and to influence the semantic distance between base and target domains (e.g., Dunbar, 2001; Richland, Holyoak, & Stigler, 2004). It may well be, then, that the reason why the novices and experts draw analogies will influence the form that the analogy takes, and we were alert to this issue in the present study.

To capture the function of analogies in our research it was necessary to use a second method of coding that was able to discriminate such nuances in analogy use. Since it was considered desirable to allow the functional aspects of analogies to emerge from the data rather than to pre-judge the issue, a qualitative assessment of expert and novice analogising was performed on the data in the form of a *thematic analysis*. Thematic analysis is a method of classifying segments of discourse that involves sorting such extracts on the basis of perceived similarities (Plummer, 1995; Smith, 1995).

Method

Participants

Sixty-four participants took part in the study. Thirty-two participants were undergraduates (23 female; 9 male), and are henceforth referred to as *novices*. Thirty-two participants were postdoctoral academics employed in

management science at various universities around the world (11 females; 21 male), and are henceforth described as *experts*. Participants were not paid. The novices were analysing cases of business situations as part of their course requirements for a final-year marketing module within their management science degree course. We acknowledge that our novices were not totally naïve to the area of business management as they possessed some relevant domain knowledge. Still, they were very inexperienced in tackling business-case problems, and the relevant knowledge that they did possess was mainly in the form of analytical concepts such as the use of SWOT analysis for considering a company's current position. The experts we studied were analysing cases as a part of workshops that they were involved in on the theme of "Teaching with Cases". These experts were all post-doctoral academics employed in management schools within universities, and thus had a wealth of advanced domain knowledge. Several of them had been practicing management for more than ten years, and thus surpassed the threshold that some researchers have claimed as a criterion for true expertise, though most fell short of this ten-year threshold by a few years. All of our participants, whether novices or experts, worked in collaborating groups during their case analyses.

Materials

There were eight novice groups that each involved four participants. Four cases were distributed equally amongst these eight novice groups (i.e., each case was initially analysed by two different groups). Groups 1 and 2 analysed "Ballygowan Springs into New Age Kisqua" (Cullen, 1996), Groups 3 and 4 analysed "The Champagne Industry in 1993" (Cool, Howe, &

Henderson, 1998), Groups 5 and 6 analysed “Petrol Retailing in Europe: The UK Market” (Lew, 1999), and Group 7 and 8 analysed “Delta Dairy S.A”. (Easton & Dritsas, 1992). The cases were 9 pages, 19 pages, 13 pages and 11 pages long, respectively.

The expert component of the study involved two sets of experts, those who were attending the Copenhagen workshop and those who were attending the Cranfield workshop. The Cranfield experts analysed two cases, “Holmesafe Ltd” (Andrews, 2000) and “East Midlands Bus and Coach Services Ltd” (Williamson, 2000), and the Copenhagen experts analysed three cases, “Graham Stewart: General Manager, A, B and C” (Erskine & Simons, 2002), “The Purchasing Co-Op” (Menor, Erskine, & Leenders, 2000), and “Jim Olson” (Leenders, 2000). All experts worked in small groups of three to five people during their initial analyses of these cases.

Procedure

The case-analysis sessions were conducted with novices at Lancaster University, UK, and with experts during two workshops held by the European Case Clearing House. One workshop took place at Cranfield University, UK and the other in the Copenhagen Business School, Denmark. These workshops were attended by participants from higher education establishments around the world and were conducted in English.

Cases were distributed to the participants before the analysis sessions so that they were familiar with the material before discussing it. Participants analysed the cases in two different settings: initial, small group discussions which lasted between 30 min and 2 hr, and subsequent large group discussions

which lasted for approximately 1 hr (with the exception that two expert analyses involved only large group discussions). The large group discussions were chaired by a *case leader*, who kept order, wrote down points and invited contributions. Small groups were self-directed by the group members. The small group discussions allowed the participants a chance to discuss the cases in order to prepare for the large group discussion. The novices were allocated into collaborating groups of four on the basis of who the module director believed would work well together and the experts worked in self-determined groups of three to five individuals.

The aim of the case analyses was for groups to design a package of recommendations that could be implemented by one of the organisations described within the case.³ The recommendations consisted of the group's analysis of the organisation's problems and their solutions to those problems. At the beginning of the analysis sessions the experimenter introduced himself and requested permission to audio-tape the sessions. During the case-analysis sessions the experimenter was a passive observer who sat quietly making notes. An audio recording was made of the small and large group discussions.

Analogy Extraction and Coding

Analogy extraction. Clement (1988) proposed four desirable attributes of a definition for recognising spontaneous analogies in participants' problem-solving discourse: (1) inclusion of attempts to produce episodes that are similar to, but different from, the target problem situation; (2) inclusion of such attempts, whether or not they ultimately yield an answer to the problem; (3) separation of analogy generation from "other" problem-solving processes;

and (4) ruling-out of trivial cases that involve only surface similarity (i.e., mere-appearance matches) without relational similarity.

Following Clement's (1988) first three principles we likewise defined an analogical episode as having occurred when a participant drew a comparison between the existing situation and a previous situation, and it could be seen that some aspects of the two situations were equivalent. We discounted analogies that: (a) were based on lectures or course materials, (b) were drawn by the Case Leader, or (c) were repetitions of previous analogies (except where the repetition was drawn to solve a different problem, or the function of the analogy changed; in these rare cases the analogies were counted as two distinct analogical episodes). Unlike Clement (1988), mere-appearance matches in the absence of any relational similarity *were* included in our analogy-extraction process, as we believed that analogies arising at this level could engender important insights about expert/novice differences in domain-based problem solving. Indeed, mere-appearance matches may well involve quite rich, and potentially useful, cross-domain correspondences that could progress problem solving. Such mappings, therefore, seem worthy of analysis.

Full analogy extraction was conducted by the first author, and a 15% random sample of the data was then analysed by an independent researcher. There was 95% agreement between the initial and subsequent analogy extraction in this reliability analysis, and disagreements that occurred showed no discernable pattern.

Coding of analogy structure. Table 1 shows an analogy that was produced by a novice during a tutorial, and will serve as the basis of the following exemplification of our coding system. The verbal extract in Table 1 indicates that the participant was tackling the problem of how to achieve increased revenue for a petrol-retail company by proposing the solution of selling advertising space close to the pumps. This was based on an analogy to what other petrol stations were doing. In our formulation of the *propositional structure* of an extracted analogical episode it was necessary: (1) to reduce the amount of information in the episode to its core, explicit, ideational and relational constructs; and (2) to draw the minimal inferences necessary to capture missing relational constructs that were sometimes omitted in the analogical episode. Inferences to complete analogies were made infrequently, and only when they seemed logically warranted. In the extract in Table 1, for example, it was not explicitly stated in the text that “companies are selling advertising space”, but this inference was a minimal necessary inference to lend coherence to the analogical episode, and also seemed entirely legitimate in the context of the analogy, as giving the advertising space away for free would conflict with the stated company aim of increasing revenue.

(Table 1 about here)

Once we had identified the propositional structure of an analogical episode in the way that we have just outlined we were then able to apply our dichotomous coding scheme to note whether the analogy was either an “object-and-attribute mapping” or a “relational mapping”. The analogical episode in Table 1 presents an example of the mapping of a higher-order

relation, in this case ‘CAUSE’, and therefore it is an example of a relational analogy. Holyoak and Thagard (1995) identify a number of different potential higher-order relationships, including CAUSE, EXPLAIN, IMPLY, ENTAIL, PRESUPPOSE, FACILITATE, HINDER and PREVENT, although CAUSE is argued by them to be the most common, and, indeed, it was predominant in our own coding of higher-order relations within analogical episodes.

The coding formalism used here is highly similar to the propositional coding of analogies employed by Blanchette and Dunbar (2000) that involved variables, relational terms and logical connectives (e.g., *and*, *if...then* and *therefore*). We present an example of Blanchette and Dunbar’s (2000) coding in Table 2 in order to illustrate their analysis approach. Our analogy example presented in Table 1 could readily be reworked into Blanchette and Dunbar’s scheme by rephrasing what we include as object names into variables. The example would then read “If X sells Y, then this causes X to increase Z”, in other words “If a company sells advertising space near the petrol pumps, then this causes the company to increase its revenue”. Critically for our structure-based analysis of analogies, both Blanchette and Dunbar’s scheme and our own Gentner-based scheme would characterise this example analogy as involving a relational mapping.

(Table 2 about here)

Coding of analogy function. In addition to coding analogies in terms of their structure, we also conducted a thematic analysis of analogies aimed at identifying the purpose or function for which they were drawn. This thematic analysis was undertaken on the original verbal extracts and was independent

of our coding of their structure. The way that we applied thematic analysis was to sort all identified analogical extracts systematically into distinct categories that reflected their identifiable, function-oriented similarities. We explored different ways of sorting the analogical extracts based on different ways in which their function could be viewed as similar. This was done until a coherent scheme was produced that accounted for the data (i.e., there were no episodes that remained uncategorized).

Results

An attempt was made in this study to observe real-world analogical problem solving in as natural a setting as possible, hence the reliance on ethnographic methods and the use of participants who were analysing business cases for a purpose outside of the requirements of the study. The use of these kinds of participants precluded the exertion of rigid control over the study procedures applied and the case-analysis problems examined across our expertise manipulation. However, it should be noted that whilst subtle discrepancies in both procedures and tasks would make the interpretation of any *differences* in observed expert and novice behaviours quite difficult, such discrepancies in procedures and tasks would arguably make the finding of expert/novice *similarities* more robust, since such similarities would have arisen despite procedural and task discrepancies.

Analogy Extraction

The expert groups produced 34 analogies in 6 hr of discussion, a mean rate of 5.6 analogies per hr ($SD = 3.8$, range = 0-12), whilst the novice groups produced 48 analogies in 19 hr of discussion, a mean rate of 2.5 analogies per

hr ($SD = 4.8$, range = 0-20). In addition to these analogy extracts a number of other extracts could be identified in which a base was articulated but where the target was not clearly identified in the surrounding discourse, although often the target could be inferred from earlier discussions or later solutions. Thirty-eight instances of this type of extract were produced by the novice groups, and five by the expert groups. These extracts were excluded from the analysis for reasons of conservatism as well as to maintain correspondence with Clement's (1988) analogy-extraction scheme. Therefore, only extracts that directly encompassed a base and a target were considered in subsequent analyses.

The Structure of Novice and Expert Analogies

Only one analogy drawn by the expert groups, and two by the novice groups, involved similarity at *only* the relational level without there additionally being a degree of superficial similarity at the level of object-and-attribute mappings (see Table 3 for an example of such a "pure" analogy). Thus the majority of analogies that were made by our participants were what Gentner (1983) would classify as being *literal similarities*.

(Table 3 about here)

In terms of the structure of the analogical mappings that were drawn, the majority of analogies generated by both novice groups (i.e., 35 or 73%), $\chi^2(1) = 10.08$, $p = .001$, and by expert groups (i.e., 25 or 73%), $\chi^2(1) = 7.53$, $p = .006$, were classified as involving relational mappings (see the right-most columns of Tables 4 and 5).

(Tables 4 and 5 about here)

The complexity of the higher-order mappings was examined further in terms of whether or not the mapping involved a nested arrangement of higher-order mappings. It was found that only 34% of the novice groups' higher-order relational mappings were nested, compared with 60% of the expert groups'. Table 6 depicts a nested analogy that was generated by an expert. This analogy expresses the idea that one person could get some repayment back from another person (who had apparently stolen from them) by forcing the purported thief to transfer property to them. This analogy was based on the previous experience of the participant, where one company had obtained a financial return from another company by forcing that company to transfer their customer contracts.

(Table 6 about here)

The Function of Novice and Expert Analogies

The thematic analysis of analogy function resulted in the emergence of two principal categories that we labelled as *problem solving* and *illustration*. The analogies shown in Table 1 and Table 6 are examples of base-to-target mappings that served the function of solving a problem. For example, the purpose of the analogy in Table 1 was to solve the problem of increasing a company's revenue, whilst the analogy depicted in Table 6 was directed toward solving the problem of a company needing to recover money. In contrast, analogies that were drawn for the purpose of illustration were designed not to facilitate directly the generation or development of a new solution idea, but instead for the purpose of exemplifying an existing idea. Such analogies, therefore, appeared to be illustrative in nature and intent,

rather than directed at problem solving per se. In such cases, the participant generated a base situation in order to *explicate* the target. In Table 3, for example, a member of the case-analysis group drew parallels between the market positions of Coca Cola and Pepsi to illustrate the position faced by an oil company that was currently under consideration in the case analysis. This comparison seemed to be drawn purely for the purpose of exemplification.

Tables 4 and 5 show the overall frequency of analogies drawn by novice groups and expert groups, respectively, for the purposes of problem solving versus illustration. Just over one-third of analogies drawn by both novice groups (i.e., 18 or 39%) and expert groups (i.e., 13 or 38%) could be classified as illustrative. Although problem-solving analogies tended to dominate the analogical reasoning of our participants, statistical analyses revealed no reliable differences in frequencies: $\chi^2(1) = 3, p = .083$, for novices; $\chi^2(1) = 1.88, p = .17$, for experts.

We further sub-divided the problem-solving category *into direct base-to-target mappings* and *elaborated base-to-target mappings*. Direct base-to-target mappings were generally of the form of “X did Y, therefore we can copy X, and also do Y”. As such, direct base-to-target mappings involved the use of an existing idea with little or no modification. In contrast, elaborated base-to-target mappings occurred when the information gained from a base analogy was used to help formulate a target solution that entailed more than simply a wholesale base-to-target mapping. In Table 7, for example, a case-analysis group was discussing the pricing strategy for a new brand of one-press champagne. The group used the price of Moët et Chandon as a

comparison to the new brand, but in order to convey the uniqueness (and therefore desirability) of the new brand they proposed increasing its price beyond that of Moët et Chandon. Rather than just simply mapping over the price of an analogous brand, therefore, the pricing solution was instead tailored to fit the properties of the new brand that the group wanted to convey.

(Table 7 about here)

Our more refined analysis of problem-solving analogies at the level of direct base-to-target mappings versus elaborated base-to-target mappings revealed that 13 (43%) of the analogies drawn by novice groups, and 9 (43%) of those drawn by expert groups, were of the elaborated kind rather than the direct kind. Thus both forms of problem-solving analogies were fairly evenly distributed in novice and expert case-analysis behaviour.

A reliability check was undertaken that involved a second sorter independently producing a second thematic analysis of all novice and expert analogies, both in terms of the problem solving versus illustration categorisation, and also in terms of the more detailed classification of problem-solving analogies as being elaborated or direct. The two thematic analyses were compared and a difference was scored if an extract had been placed in a different position in the two analyses. Consistency between the two coders was high, at 87% (i.e., only 7 out of 55 extracts were placed differently).

The Structure and Function of Analogies Compared

Tables 4 and 5 also present the frequency of analogies serving the purpose of problem solving versus illustration that arose when participants

either generated object-and-attribute mappings or relational mappings. This breakdown of analogies allows a comparison to be made of the association between functional aspects of analogising and the structure of the mapping process across levels of expertise. A maximum likelihood chi-square test (Bishop, Fienberg, & Holland, 1975) exploring the structure by function interaction (collapsed across level of expertise) revealed a significant difference between observed and expected frequencies of analogy production, $G^2(2) = 31.17, p < .0001$. Looking at problem-solving analogies first, it is evident that participants invoked analogies that primarily involved relational mappings (exclusively so in the novice case), $\chi^2(1) = 39.7, p < .0001$. In contrast, when analogies were drawn for the purpose of illustration, novices were more likely to use object-and-attribute mappings than relational mappings, a difference that was marginally significant, $\chi^2(1) = 3.55, p = .059$, whereas experts showed no preference in the mappings that were employed, $\chi^2(1) = .077, p = .78$.

Discussion

Our study of novice and expert case analysis in a management context has produced a number of findings that clarify the nature and role of analogical reasoning in real-world problem solving. First, we have demonstrated that novices working in groups are able to use analogies spontaneously to progress problem solving in a similar manner to that previously observed in experts (e.g., Clement, 1988; Dunbar, 2001; Dunbar & Blanchette, 2001; Marchant et al., 1993). Second, we have observed no major differences between novice and expert groups in the extent to which generated

analogies are structured around relational mappings compared with those that are structured around purely object-and-attribute mappings. In general, both novice and expert analogising was dominated by analogies that mapped relational structures between base and target domains. This finding demonstrates a sophistication in the application of knowledge that is not usually associated with novices (though see Blanchette & Dunbar, 2000). Third, we have found that the analogies that both expert and novices groups drew were directed toward the attainment of two main practical goals: problem solving and illustration.

The latter observation -- that analogies serve different functions -- is in line with Dunbar's (2001) proposal that analogies may be drawn for different purposes in applied contexts (see also Blanchette & Dunbar, 2001). Moreover, our results also support Dunbar's (2001) claim that the structure of participants' analogical mapping may change, depending on the function of the mapping. Thus, we saw that problem-solving analogies were dominated by relational mappings, whereas illustrative analogies were dominated by pure object-and-attribute mappings. We note, though, that this cross-over pattern was more marked in the analogical reasoning of novices than experts, and may, therefore, need to be interpreted with a degree of caution. In general, however, it is clear that the low level of object-and-attribute mappings that arose for both experts and novices when an analogy was designed to solve a problem attests to the importance of relational associations between base and target situations for facilitating effective problem solving. The fact that analogies that were aimed at illustration often involved pure object-and-

attribute mappings without relational mappings is intriguing. It may well be that illustrating an idea can frequently be achieved simply and effectively via a low-order correspondence between quite superficial elements of the base and target situations.

In terms of methodological aspects of our research, we note that the usual method of constructing an experiment is to have two groups who are similar in as many ways as possible except for the variables of interest (the independent variables). In real-world situations of the type that pertained in the present study, it is not always possible to create experiments with such tight control over variables. In particular, the practicalities of doing research in real-world domains means that the settings in which research data are collected are often less than ideal. Owing to the difficulty of collecting data in the present study, we admit to being unable to exert as rigorous a level of control as we would have liked over the way that our participants analysed their given cases -- or, indeed, the cases that they were presented with. As we noted earlier, however, whilst such confounds in the nature of tasks and procedures might arguably have invalidated any examination of key *differences* between our two groups, we contend that it makes our findings of marked *similarities* more compelling since such similarities have arisen in spite of differences in tasks and procedures. At a methodological level, too, we are aware that whilst our novices certainly had considerably less domain knowledge than our experts, our ability to polarise our novice and expert participants into those with complete domain naïvety versus those with full-blown domain expertise was imperfect. Nevertheless, we believe that our

results remain a valid examination of analogical reasoning in management individuals with very different levels of domain knowledge along the expertise continuum.

Overall, then, our results suggest that unprompted analogising may well be a generic problem-solving strategy that novices, like experts, are able to deploy (cf. Holland, Holyoak, Nisbett, & Thagard, 1986). We propose, however, that contextual factors arising from the use of meaningful, real-world tasks may be critical for observing such spontaneous analogising in novices. In management domains, for example, individuals are able to draw on a wide range of personal and everyday experience that provides valuable background knowledge that can fuel analogy-based reasoning. Thus, whilst our management novices were a long way off from being true domain experts, the sheer richness of their everyday experience may have enabled them to utilise knowledge in similar ways to how experts employ their more specialist domain-based knowledge. It seems clear that some real-world domains would allow individuals to draw more fully on everyday knowledge than others. For example, business management, political science, and creative design are all domains where a rich backdrop of non-specialist knowledge can be applied to progress solutions to problems. The extent to which the observation of spontaneous analogical reasoning generalises across a range of applied domains is an issue that needs further empirical examination.

As a final point, we note that the vast majority of the analogies that were drawn by both novices and experts were what Gentner (e.g., 1983; see also Gentner & Markman, 1997) would term *literal similarities* rather than

pure analogies, as they involved a mixture of both object-and-attribute and relational mappings. This observation is consistent with research that has found that the search for an analogy is often based on superficial features of the target information (e.g., Gentner, Ratterman, & Forbus, 1993). The result would also be predicted by the MAC/FAC model of analogy proposed by Forbus, Gentner, and Law (1995), who argue that the search for potential analogies is based on superficial problem features, with the deeper-level structure of the base and target predominantly influencing the mapping stage. Although we agree that superficial similarities between base and target situations are likely to be very important in the search process, other evidence indicates that structural similarity may also play a role in the search for a base analogue (cf. Wharton, Holyoak, Downing, Lange, Wickens, & Melz, 1994). Indeed, in the ARCS model of analogical retrieval proposed by Thagard, Holyoak, Nelson, and Gochfield (1990), structural aspects of the target can influence the search process.

We conclude by noting an important qualification to our results, which is that our research, because of its very focus on spontaneous, real-world analogising, is quite distinct from the majority of analogical problem-solving research, with its laboratory-based emphasis. Indeed, our study differs from the conventional research approach in at least three key respects. First, analogies in our study could be drawn from any area of a participant's experience; the experimenter did not provide the base information. Second, participants solved the problems in groups rather than individually. Third, the participants had extended periods of discussion-based activity that was geared

toward analysing and solving the presented problem. It is clear that our method of exploring analogising represents a very different paradigm to the standard experimental approach, such that direct comparisons between the two should be drawn with caution. However, considering that experiments on analogy are themselves supposed to be analogues of real-world situations (though in a more controlled and scaled-down form), a reconsideration of how analogical problem solving can fruitfully be investigated experimentally may need to be undertaken. This is especially so in the light of mounting evidence that both novices and experts can frequently and spontaneously make good use of sophisticated analogies in their real-world problem solving.

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Footnotes

¹Some of our following examples of predicate structures and analogical mappings are derived from those presented in Holyoak and Thagard (1995).

²It should be apparent that higher-order argument structures can contain nested relations of potentially considerable complexity.

³Most of the cases referred to in the paper are available from the European Case Clearing House at <http://www.ecch.cranfield.ac.uk>

Table 1

An Analogy Produced During a Novice Group's First Session when Focusing on the "Petrol Retailing in Europe" Case

Analogy produced

Participant 1: "They've got adverts. That's a possible suggestion -- the advertising just getting increased revenue -- is to get advertising spots by the pumps. A lot of stations are doing that, and they even have now TV screens so you get other companies advertising at your petrol station. It might be an idea to increase revenue".

Propositional structure of the analogy

Base: CAUSE [SELLS (Company-X, Advertising-Space-Near-Petrol-Pumps), INCREASE (Company-X, Revenue)]

Target: CAUSE [SELLS (Company-A, Advertising-Space-Near-Petrol-Pumps), INCREASE (Company-A, Revenue)]

Table 2

An Example of the Structure of an Analogy Created by Blanchette and Dunbar (2000) by Substituting Variables for Object Names (see Blanchette & Dunbar, 2000, p.112, Table 2)

Analogy produced

Social programs are needed

If social programs are cut

Then negative consequence

Therefore, don't cut social programs

Propositional structure of the analogy

X is needed

If X is eliminated

Then negative consequence

Therefore, don't eliminate X

Table 3

A “Pure” Analogy Produced During a Novice Group’s Second Session when Focusing on the “Petrol Retailing in Europe” Case

Analogy produced

Participant 1: “You know, you said the other day that Coca Cola and Pepsi are within an arm’s reach -- there's not much of a differentiation. It's the same here”.

Propositional structure of the analogy

Base: CLOSE-MARKET-POSITION (Coca-Cola, Pepsi)

Target: CLOSE-MARKET-POSITION (Petrol-Station-X, Petrol-Station-Y)

Table 4

Frequency of Analogies Produced by Novices, Categorised by their Structure and Function

Structure	Function		Total
	Illustration	Problem Solving	
Object-and-Attribute Mappings	13	0	13
Relational Mappings	5	30	35
Total	18	30	48

Table 5

Frequency of Analogies Produced by Experts, Categorised by their Structure and Function

Structure	Function		Total
	Illustration	Problem Solving	
Object-and-Attribute Mappings	6	3	9
Relational Mappings	7	18	25
Total	13	21	34

Table 6

An Analogy Produced by an Expert (Copenhagen Study, Large Group Discussion) when Focusing on the “Graham Stewart: General Manager, A, B And C” Case

Analogy produced

Participant 1: “He’s been foolish not to check. He’s to try to get as much money as he can. Bring muscle along, almost illegally”.

Participant 2: “He’s already undermining us. Get him to sign the property over to us. It’s an option but it needs a lot of muscle”.

Participant 1: “We had a similar situation when a major customer closed down. We got him to sign over the contracts so we were paid by the customers”.

Propositional structure of the analogy

Base: CAUSE [GET (Company-X, Money-From-Debtor), CAUSE [FORCE (Company-X, Debtor), TRANSFER-CONTRACTS (Debtor, Company-X)]]

Target: CAUSE [GET (Person-A, Money-From-Debtor), CAUSE [FORCE (Person-A, Debtor), TRANSFER-PROPERTY (Debtor, Person-A)]]

Table 7

An Example from a Novice Group's Second Session of a Participant Producing an Elaboration of a Basic Mapping when Focusing on the "Champagne Industry In 1993" Case

Analogy produced

Participant 1: "Another thing that we were having difficulty coming up with is an actual price, because we were thinking, 'Shall we out-price Moët et Chandon by only a small amount, because it gives that exclusivity, and we didn't want to go for exactly the same price because we've got this unique selling point?' So if you just did it a tiny bit more expensive, going to that bit much it's as good as and it's got this unique selling point, and it's only a tiny bit more so that it's not too much of a stretch to buy it over Moët et Chandon. So people realise that it must be better, because it's that bit more expensive, and it's got this unique selling point".

Propositional structure of the basic analogy prior to its elaboration

Base: ENABLE [AS-INDEXED-BY (Product-Quality-And-Exclusivity, High-Price), IMPLEMENT (Moët-et-Chandon, Marketing-Strategy)]

Target: ENABLE [AS-INDEXED-BY (Product-Quality-And-Exclusivity, High-Price), IMPLEMENT (Company-Y, Marketing-Strategy)]

Propositional structure of the elaborated solution

CAUSE [MORE-EXPENSIVE-THAN (Company-Y-Champagne, Moët-et-Chandon-Champagne), MARKET-ADVANTAGE-OVER (Company-Y, Moët-et-Chandon)]
