## Title
Empirical Evidence for Derivational Analogy



## Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 21(0)

## Authors
Schmid, Ute
Carbonell, Jaime

## Publication Date
1999

Peer reviewed

# Empirical Evidence for Derivational Analogy

**Ute Schmid (schmid@cs.tu-berlin.de)**
Department of Computer Science, Technische Universität Berlin
Franklinstr. 28, 10587 Berlin, Germany

**Jaime Carbonell (jgc@cs.cmu.edu)**
School of Computer Science, Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, PA 15213, USA

Analogical problem solving is mostly described as transfer of a source solution to a target problem based on the structural correspondences (mapping) between source and target. Derivational analogy (Carbonell, 1986) proposes an alternative view: A target problem is solved by replaying a remembered problem solving episode. Thus, experience with the source is used to guide the search for the target solution by applying the same solution technique rather than by a transferring the complete solution. We postulate that both transformational (TA) and derivational analogy (DA) are problem solving strategies realized by human problem solvers. Which strategy is evoked in a given problem solving context depends among other factors on the problem domain. A problem can be solved easily by TA, if the domain involves few objects and relations and/or there are strong (semantic) constraints for mapping; otherwise using DA is more efficient.

We investigated this hypothesis in an empirical study. An example for a domain where TA on an analytical level is inefficient are the network problems presented by Novick and Hmelo (1994). The authors presented (1) an island problem, where a travel route has to be calculated such that each bridge connecting pairs of islands is travelled exactly once, and (2) a handshaking problem, where the goal is to figure out who shook hands with whom at a cocktail party. The first problem corresponds to finding an Eulerian trail in a graph, the second to finding a Hamiltonian cycle. We modified these problems such that the underlying graphs are isomorphic (have the same number of nodes and arcs and identical structure). For each problem class we constructed an additional problem, embedding it into a different context. We used the following problems as source candidates: Euler/travel (*islands*), Hamilton/party (*cocktail*), Euler/party (*birthday*), and Hamilton/travel (*castles*). As target problem we used another Eulerian trail problem from the travel domain (fig. 1) which again could be represented by the same graph.

Because there are no constraints for mapping (unknown) cities to other cities or names of (unknown) persons, node-to-node mapping has exponential effort – that is, TA is a highly inefficient strategy. In our study we wanted to explore if people prefer DA to TA to solve such graph problems and which variables are suitable to discriminate between DA and TA.

**Method.** Ten subjects were presented first with the four source candidates (in one of two permutations). They had 5 *min* to try to solve each problem and were presented with the solution afterwards. Then, they read the target problem, were asked to select one of the source candidates, and to solve the target problem. To discriminate between DA and TA we (1) obtained thinking aloud protocols during problem solving, and afterwards (2) asked subjects to map (a) global concepts of source and target (boat, rivers, river locks, cities), and (b) the concrete objects (the cities Schwetzingen, Blaubeuren, etc.) which correspond to the nodes in the graph. For both mappings subjects were instructed to answer each question only if they have the source correspondence available and otherwise skip the question. Finally, (3) subjects were asked to select one from seven predefined strategies. Among these strategies were (a) abstraction, (b) TA (*Because I think that the example problem and the boat problem are very similar, I just tried to replace the node labels in the graph of the example solution with the corresponding names of the boat problem*), and (c) DA (*I remembered how I solved the example problem, that is, how I constructed the graph and how I found the required path in the graph and did it in the same way for the boat problem*).

> **Boat.** [...] The eight [river] locks are located between the following pairs of cities: Schwetzingen and Blaubeuren, Schwetzingen and Ludwigsburg, Schwetzingen and Marbach, Marbach and Ludwigsburg, Marbach and Blaubeuren, Blaubeuren and Ludwigsburg, Blaubeuren and Ulm, Ulm and Ludwigsburg. The Hamiltons plan to start their trip in Schwetzingen. From Schwetzingen, they wish to travel along a route on the rivers that will enable them to go through each of the eight locks exactly once. Note that their desire to travel through every lock once necessarily means that they will visit some of the cities more than once. Plan a route for the Hamiltons so that they travel over through every lock exactly once and visit each city as many times as necessary.

Figure 1: Target problem (abridged)

Our results are promising: Six subjects reported DA, two TA, and two abstraction. Verbal protocols correspond to the strategy reports. Results for node-to-node mapping are not conclusive, however. Our hypothesis was that only subjects using TA should be able to give these mappings easily. But two subjects reporting DA gave the correct mapping and one subject reporting TA did not give the correct mapping. But this subject was the only of the ten which could not produce a correct solution of the target: she tried to draw the graph in exactly the same layout which was given for the source solution and thereby missed one arc.

The results suggest that DA – although proposed in an AI context – is a strategy employed by human problem solvers. To strengthen our claim that humans use TA when mapping effort is low and DA otherwise, we plan follow-up studies contrasting domains with few vs many constraints for node-to-node mapping.

## References

Carbonell, J. (1986). Derivational analogy: A theory of reconstructive problem solving and expertise acquistion. In R. Michalski et al., *Machine learning – An AI approach* Morgan Kaufmann.

Novick, L. R., & Hmelo, C. E. (1994). Transferring symbolic representations across nonisomorphic problems. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(6), 1296-1321.