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Ten years of research on letter string problem solving by Meta-Analogical Transfer

Diez años de investigación en solución de problemas de secuencias de letras por transferencia meta analógica

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Resumen

Se cumplieron ya diez años desde que el primer trabajo sobre solución de problemas de secuencias de letras por transferencia analógica fue publicado. Desde entonces un número importante de estudios sobre el tema han intentado replicar el hallazgo seminal. En general las replicaciones han producido resultados negativos o inconsistentes. El presente trabajo revisa la literatura producida desde entonces y examina las variables que modulan el fenómeno. El presente trabajo también sugiere que la agenda de investigación y las políticas editoriales relacionadas con la solución de problemas por transferencia analógica deberían ser revisadas cuidadosamente.
Palabras clave: Transferencia meta-analógica, solución de problemas de secuencias de letras, revisión.

Abstract

It has been nearly ten years since the first study on letter string problem solving by meta-analogical transfer was published. Since then a number of studies on the subject have attempted to replicate the seminal findings. In general replications have produced inconsistent or negative findings. This paper reviews the experimental literature produced so far and examines the variables that modulate the phenomenon. The paper also suggests that the current research agenda and the editorial politics regarding problem solving by analogical transfer should be carefully reviewed.
Key words: Meta-analogical transfer, letter string problem solving, review.

After an initial interest during the early decades of the twentieth century, research on problem solving by analogical transfer remained relatively dormant for a number of years. Seminal studies by Reed, Earnst & Banerji (1974) and Gick and Holyoak (1980; 1983) made problem solving by analogical transfer one of the central topics of the cognitive revolution. Most of the research produced during the first ten years following the Gick & Holyoak studies focused on identifying strategies that would allow previously solved problems to change the probability of solving new similar problems.

Initial studies produced generally discouraging results that either showed that previous programmed experiences had little effect on new similar target problems or that endless repetition of practice problems were required in order to generate any evidence of analogical transfer. Leaving the issue on how to produce analogical transfer more or less unresolved (Lave, 1988), scientists began to explore three different aspects regarding problem solving by analogical transfer. For starters, during the early nineteen nineties a number of studies regarding analogical transfer in different knowledge domains began to appear (Bassok & Holyoak, 1989; Bassok, 1990 Novick & Holyoak, 1991). Simultaneously studies regarding the importance of superficial similarities in analogical transfer began to appear in different journals. This later research focused principally on how subjects use non structural criteria to determine similarity between problems, and how this "solution strategy" is relatively widespread and much more common than structural similarity, as a tool for determining analogical solutions between problems (Holyoak & Koh, 1987; Ross, 1989; Heydenbluth & Hesse, 1996; Ross & Kilbane, 1997). Lastly a number of studies regarding computer simulation models of analogical transfer also appeared in numerous journals (Falkenhainer, Forbus & Gentner, 1989; Mitchell, 1993; Hofstadter & Mitchell, 1994). Publications on problem solving by analogical transfer during the last ten years, have centered primarily on promoting the findings and technological developments generated by the scientists interested in this phenomenon (Gentner & Holyoak, 1997; Gentner & Markman, 1997; Tuomi-Grohn & Engestrom, 2003; Darling-Hammond & Bransford, 2007).

The view in our Laboratory, towards this rapidly unfolding research and merchandizing agenda, has been one of general distrust. Specifically we believe that the fundamental issues regarding the production of analogical transfer are still generally unsolved and that studying this phenomenon using complex procedures and subsequently developing them into computational models and self-help books is irresponsible. Consequently we have developed our own research agenda; this agenda is based on results produced by very simple problems (commonly known as letter string problems) that allow relatively clear ways of manipulating and identifying independent variables. We have consistently used letter string problems to address what have appeared to us as the fundamental questions relating the production of reasoning by analogical transfer. This approach has not only allowed us to shed light on some still unresolved and fundamental issues, it has also permitted us to generate comparable results between studies (Pulido, 1999; Pulido, 2002; Pulido, Olmos & Lanzagorta, 2005; Pulido, Barrera, Huerta & Moreno, 2008; Pulido, de la Garma & Pérez, 2010). The following section will be used to further describe our general experimental approach.

On Letter String Problem Solving

Letter string problem solving was originally used in the area to develop and assess computational models of analogical problem solving. It was first used in experimental research with humans by Burns (1996) to assess meta-analogical transfer (the use of previous transfer episodes in the solution of new similar problems). In his seminal study Burns presented students with a problem that demanded a first episode of analogical reasoning "If ABC is deliberately changed to ABD, how would you change MRRJJJ in the same way?" (In Burns´s notation ABC:ABD-MRRJJJ?). Burns observed that the experimental subjects frequently changed MRRJJJ to MRRKKK (in agreement with the initial model where the last letter is changed from C to D). Response strategies in letter string problem solving were referred to as "predicates" by Burns, the particular response strategy presented previously was classified by Burns as a successor-successor predicate because in both letter strings (ABC and MRRJJJ) the last letter is changed for the immediately successive letter in the alphabet. Burns reported that those subjects that produced an MRRKKK response,

had and increased probability of using a successor-successor predicate when confronted with the problem ABC:ABD-KJI (most subjects who received this problem sequence produced KJJ as an answer; subjects that received the problems in inverse order only produced KJJ as a response sporadically). Burns found essentially the same answers when instead of asking the subjects to produce a response he gave them different alternatives and presented them with a rating scale (KJJ was rated higher when the subjects received ABC:ABD-MRRJJJ? as a first problem, and considerably lower when they received ABC:ABD-KJI? as first problem). The author demonstrated the generality of his finding by producing data that suggest that meta-analogical transfer my also occur when successor-predecessor response strategies are required (subjects that were taught that KJH was the correct answer to the problem ABC:ABD-KJI? rated WYZ as a better answer than XYD to the problem ABC:ABD-XYZ?).

And, What Happened Next?

Around 1997 we finished reviewing the experimental procedures used by scientists interested in problem solving by analogical transfer. We were looking for a relatively simple experimental procedure that would allow an easy identification of independent and extraneous variables; we were also looking for an experimental procedure that would produce relatively straightforward and robust effects. Burns´s procedure appeared to possess all the attributes we were looking for, with the added benefit of suggesting several easy ways to measure the dependent variable. Our first experiment, produced using this procedure, was designed to determine if the putative meta-analogical effects, reported by Burns in fact existed (Pulido, 1999). With this objective in mind we painstakingly replicated Burns seminal study and simultaneously recorded the verbal protocols of the experimental subjects. In general, the verbal protocols obtained in the study corresponded with Burns interpretation that the predicate developed during the first analogical episode was used again when the subjects were confronted with a second similar analogical episode.

The results of the first study suggested we had chosen an experimental procedure that met our expectations; it also suggested that the optimistic reports we had been reviewing (in particular the monographic number on analogical transfer published by the *American Psychologist* in 1997) were based on solid evidence.

A second study was designed to determine the generality of Burns´s findings (Pulido 2002). Specifically this follow up study was designed to determine if meta-analogical transfer could occur in problems that required solutions based on predecessor-successor and predecessor-predecessor predicates. Using the rating procedure developed by Burns, 400 university students were assigned to four different experimental groups. Subjects assigned to the predecessor-successor condition were taught one of two different solutions to the problem XYZ:WYZ -ABC? (either WBC or ABD). It was hypothesized that those subjects that were taught an ABD solution, would assign higher ratings to and LJI solution to the problem XYZ:WYZ-KJI? (because both solutions are based on a predecessor-successor predicate). In a similar way, subjects exposed to a predecessor-predecessor condition were taught two different solutions to the problem XYZ:WYZ-BCD? (either ACD or WCD). It was hypothesized that those subjects that were taught the ACD solution would assign higher ratings to an JJI solution to the problem XYZ:WYZ-KJI? (because both solutions are based on a predecessor-predecessor predicate). Results showed robust meta-analogical transfer effects when subjects were exposed to problems that required a predecessor-predecessor solution; no evidence of meta-analogical transfer was found in subjects exposed to problems that required a predecessor-successor solution.

These results are in stark contrast with those produced in his seminal study by Burns, and thus an explanation for the discrepancies between studies became the top priority in our research agenda. After much consideration we were left with two different possibilities. In first place, it was possible that despite Burns's success in demonstrating meta-analogical transfer using problems that required a successor-predecessor solution, somehow, solutions that required a bidirectional movement of letters (successor-predecessor or predecessor-successor) are more difficult to solve than problems that only require moving letters in one direction (successor-successor or predecessor-predecessor). And thus demonstrating analogical transfer in bidirectional problems is more complicated than demonstrating

the phenomenon using unidirectional ones. A second possible explanation for the discrepancies derived from the augmenting number of studies suggesting analogical transfer is mediated by superficial rather than structural similarities between problems. In brief, results from the 2002 Pulido study show that subjects rated the alternatives to the successor-predecessor problem (LJI and HJI) equally high, however, responses to the predecessor-predecessor problem (JJI and LJI) contrasted sharply (JJI was rated consistently lower than LJI). This results suggest that subjects could be rating answers in terms of the alternatives having (or not) the same number of letters as the initial problem (and thus they should chose indifferently between answers with the same number of letters as the model, and should considerably punish ratings for those answers with a different number of letters than the model).

The two possible interpretations led to a new study (Pulido, Olmos & Lanzagorta 2005) that systematically assessed the effects of type of problem, and superficial similarities on problem solving by meta-analogical transfer. A total of 1136 college students were divided into 16 different experimental conditions; the study may be conceptualized as a factorial designed with three different factors: problem type (successor-successor; successor-predecessor, predecessor-successor, and predecessor-predecessor); superficial similarities between the model and the answers to be rated (present or absent); and transfer modality (subjects either received a model that demonstrated a structural solution to the problem or received a model that demonstrated object transfer (object transfer was defined by Burns as a solution that "simply" requires inserting the same letter that was changed in the model in the new letter-string problem, this condition is generally used as a control condition that allows the assessment of the effects of the structural transfer model)). In general, results showed no evidence of meta-analogical transfer in any experimental condition (structural transfer conditions produced essentially the same ratings as the control conditions); however the effects of the independent variables on the ratings of the "correct answer" had robust effects. Results showed the correct answer was consistently underrated when subjects received bidirectional problems; the correct answer was also consistently underrated when instead of presenting three different letters (as did the model), it only presented two different letters.

This last study had important sobering effects on our study group. The results confirmed our hypothesis that the inconsistent data produced by the 2002 study were by no means an isolated case. It also showed that the ever present transfer modulator, superficial similarities, had robust effects on letter string problem solving.

Lack of transfer effects, in our studies regarding meta-analogical problem solving, are by no means isolated cases within the scientific production of the area (see Lave, 1988 for a review). Reed, Dempster, and Ettinger (1985) produced data that suggested that weak transfer effects could be boosted by allowing the subject to constantly return to the solution model. In the present studies, solution models and target problems were printed in separate pages, and although no constraints were implemented to restrain the subject from returning to the model, we hypothesized that separated printing could hinder transfer effects. In order to assess this possibility, Pulido, De la Garma, and Pérez (2010) exposed 542 college students to an experimental procedure that assessed the effects of model and target problem printing (on the same and on different pages) on problem solving by meta-analogical transfer. The study may be conceptualized as a factorial 2x2x2x2 design with model and target problem printing as first independent variable; model usefulness as second independent variable (structural transfer or object transfer model); superficial similarities between the solution model and the target problem as third independent variable (present or absent) and problem type as fourth independent variable (successor-successor or successor-predecessor). In agreement with the Pulido, Olmos, and Lanzagorta (2005) study, the results showed no evidence of meta-analogical transfer (structural transfer and object transfer models produced very similar "correct response" ratings). Transfer effects were almost identical, regardless of the subjects receiving model and target problem in the same or different pages of the booklet. Once again, unidirectional problems produced significantly higher rates for the correct response than bidirectional problems. In agreement with the Pulido, Olmos, and Lanzagorta (2005) study, the effects of superficial similarities were robust, as answers with the same number of different

letters as the model produced significantly higher ratings than answers that were not similar to the model in this respect.

One last attempt, developed in our Laboratory, to try to account for the inconsistent and negative findings reported so far, is based on the hypothesis that equivalent letter string problems do not produce equivalent results. The computer models designed so far to assess theories regarding problem solving by analogical transfer, have assumed that equivalent letter string problems should produce equivalent effects (Mitchell, 1993; Hofstadter & Mitchell, 1994). Due to the fact that most of the studies presented so far have used different "equivalent" letter string problems (in order to determine the generality of Burns seminal study), lack of systematic findings could be attributed to lack of true empirical equivalence between problems. Pulido, Huerta, Barrera, and Moreno (2008) asked 495 college students to solve one of twelve different letter string problems. These problems were grouped in two different families (three or six letter target problems). Problems in each family were carefully developed in order to guarantee their structural equivalence (distance between words was maintained constant and all target problems used letters that were located in the center of the alphabetical continuum). Results showed large differences in response variability within each family group; problem solving strategies also varied significantly within each family. In order to determine if these differences affected meta-analogical transfer, the most contrasting problems assessed in the first experiment were used in a second one to try to produce meta-analogical effects. A total of 325 college students were asked to solve one of two different pairs of letter string problems. Some students solved the problem with the highest response variability (ABC:ABD-MRRJJJ?); others received the problem with the lowest response variability (ABC:ABD-FKKCCC?). Both groups received the problem ABC:ABD-EDC? (after solving the first problem); meta-analogical transfer effects were assessed by comparing response distribution on the second problem. Results showed that the subjects that received the ABC:ABD-MRRJJJ? problem produced equivalent amounts of EDD responses (identified by the authors as the "correct answer") and other responses. In contrast, those subjects that received the ABC:ABD-FKKCCC? problem, produced significantly lower frequencies of EDD answers and considerably higher frequencies of other responses. In synthesis, equivalent letter string problem models produce different meta-analogical transfer effects.

Conclusion

Our interest in letter string problem solving by meta-analogical transfer was ignited by what we assumed was a simple experimental procedure with relatively robust effects and a quantifiable dependent variable. Our studies have shown that the experimental procedure does not produce strong transfer effects or that the dependent variables assessed so far are not sensitive to these effects (or both). When confronted with negative findings, reactions amongst scientists interested in problem solving by analogical transfer have differed. Some scientists have claimed that the phenomenon does not exist, or is irrelevant for the learning process (Lave, 1988); others have shown disregard for them and have busied themselves with selling a yet unripe scientific product (Gentner & Markman, 1997); still others have tried to account for the "anomalous" results (Catrombone & Holyoak, 1989; Gick & Holyoak, 1983; Reed, Dempster & Ettinger, 1985). The present authors tend to coincide with the latter approximation in that negative findings within the field should be dealt with, and that the research agenda should be dictated by them. As our experimental findings have produced mainly negative results, our research agenda is already displayed before us. In the meantime we hope that the present review will help scientists interested in the phenomenon to return to the laboratory and carefully review their experimental procedures. We also hope that theory development within the field acquires a more careful tenure and that technological developments be painstakingly and empirically assessed before they are presented to potential consumers. Additionally we sincerely hope that the present review will revive interest in the issue of editorial politics in scientific journals. Specifically we hope that the tendency to publish exclusively those papers that reject the null hypothesis be revised because the present authors suspect that the failure to replicate findings published in scientific journals could possibly be accounted for in terms of scientists showing the editors "publishable" results (and withhold-

ing negative findings that will not be accepted by the journals but that would help other scientist have a more complete and unbiased understanding of a particular study field).

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