PROCESSING DIFFERENCES BETWEEN NEAR AND FAR ANALOGIES

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Abstract: *It has been shown, that far analogies do engage more cognitive resources than near analogies. Word couples of the A goes to B as C goes to D (A:B :: C:D) kind are mapped slower and more mistakes appear if comprised of far (Tongue:Taste :: Antenna:Signal), rather than near analogies (Tounge:Taste :: Nose:Smell). According to Adam Green, that is because in the Working Memory (WM) there will be too much information when it comes to comparing the far analogies.*

*That explanation was tested in the current paper. The presentation of elements, comprising simple verbal analogies were varied at four levels: no information is shown to the entry; element A is only visible at the entrance; A:B are shown and the first three elements are visible A:B :: C***:.** *If mapping of far analogies truly requires more cognitive resources to be available as the results of Green's study indicate, the time for the encoding of the three elements at the entrance, shall be longer for far compared to near analogies, since the mapping between the pairs can be initiated under that condition. Such distinction is not to be expected when it comes to the other three (0; A:; A:B) conditions.*

The collected results show that near analogies are addressed more accurate and faster that the far ones. The way of presentation affects the participant's time for response, but not how accurate, they might be. Results for the encoding type reveal a main effect for way of presentation, but none for type of analogies and insignificant interactions between them. The mapping of far compared to near analogies was found to be not significantly slower, although this was suggested to be the cognitively demanding part for the far compared to near analogies.

Keywords: *analogies, near, far, encoding, mapping, evaluation*

Introduction

Analogy allows comparison between featurally unlike structures to be performed on the basis of relational similarity (Holyoak, 2012). Analogical mapping allows finding of systematic correspondences between the source and target situation based on shared relations (Tohill & Holyoak, 2000). People seek to put the objects of the source in one-to-one correspondence with the objects of the target, so as to obtain the highest structural match. The corresponding objects in the base and target need not resemble each other, the importance here is that, they hold alike roles in the matching relational

structures. A well-understood base or source situation is mapped to a target situation that is less familiar and/or less concrete. Then new inferences are derived by importing connected information from the source to the target. A good example would be the following: in the analogy between blood circulation and plumbing, people might first align the known facts that the pump *causes* water *to flow through* the pipes with the fact that the heart (being a unique, alive pump) is the prime *cause* which moves the blood to *pour through* the veins. When comparing the heart with a pump, we are practically saying: *"Heart is to blood, as pump is to water."* Afterwards blood returns to the heart to be re-cycled and re-poured again and again, creating an ideal, closed system cycle (Gentner, 1982).

According to the *Structure Mapping Theory,* analogy-making requires first a selection of the primary candidate number of predicates to map attends only to the *structure* of the knowledge representations for the two analogs, and not the content. The mapping takes place not only between objects, but also between relations among objects (i.e. first-order predicates) and between relations of relations (i.e. second-order predicates). The whole mapping yields the assignment of a predicate or a relation to the target.

Gentner (1982), proposed that in order to facilitate the making of clear alignments and reasonable inferences, an analogy must be structurally consistent, meaning: it should have one-to-one *correspondences*, and the relations in the two domains should have a parallel structure. With respects to the circulation/plumbing system analogy, the pump cannot correspond at the same time to the veins and the heart. Another factor influencing the quality of it, is *systematicity*: Analogies that convey an interconnected system of relations, such as the circulation/pumping analogy, are more useful than those that convey only a single isolated fact, such as ''*The brain looks like a walnut*.''

Near and Far Analogies

When a new highway system is about to be designed, the devisors could draw a near analogy – another highway system from another city, which in its essence is deriving an analogy from a closely related base domain. On the other hand, a more distant domain that can act as a base, say the human blood circulatory system. This distinction is important, since mapping and transferring elements (objects, attributes, relations) are different with respects to both analogy types (Dahl & Moreau, 2002). When near analogies are drawn, both surface-level attributes (roads) and the relations between the attributes (the course of automobiles through the highway) are mapped and transferred. When it comes to far analogies, however, much less surface-level attributes can be mapped, and thus leaving the mappings to occur between common relations. When the base and target realms pose few such similarities, the process itself becomes limited and uneasy to deal with (Dahl & Moreau, 2002).

The difference between near and far analogies can be defined, as analogies being derived from semantically afar fields, and are also referred to as within-domain (near) and cross-domain (far) analogies (Green, Fugelsang, Kraemer & Dunbar 2008; Green, Kraemer, Fungelsan, Grey & Dunbar, 2010). Green et al (2006a; 2008; 2010), show an apparent relationship between semantic distance of analogical mapping and proportional recruitment of the frontopolar cortex. The fMRI data has shown that the frontopolar cortex is recruited more strongly for the mapping of cross-domain (i.e. Nose:Scent :: Antenna:Signal) analogies than within-domain (i.e. Nose:Scent :: Tongue:Taste). Moreover, frontopolar activity largely reflects a taxonomic (etymologically: "law of order of arrangements", nowadays known simply as a science of classification of things or concepts) distinction, between these classes of analogy (Green et al, 2010). Semantic distance values were used as parametric regressor, which allowed regions of the brain, where semantic distance collaborated with stimulus-related activity in a relationship to be identified. Furthermore, even after these measures of task difficulty were excluded, the semantic distance still covaried positively with activity in the frontopolar ROI. These results highly suggest that difficulty-related factors cannot explain the affinity between semantic distance and frontopolar activity and are also consistent with previous work, indicating that specific task arrogations of multiplex reasoning, rather than time-on-task or difficulty by its very nature, accounts for frontopolar enrolment (Green et al, 2010). Further, the results implicate a degree of frontopolar activation as a marker of semantic distance in analogical reasoning. When the cortical activity is to be increased, proportionally it could reflect in increasing the fixed calculational demand on the neuronal integration network (Green et al, 2010). Relations between AB and CD should be represented in much abstract form during analogical mapping of far analogies but not necessarily during near analogies. Also mapping between far compared to near analogies is more likely to be ambiguous (i.e. enabling several alternative mappings between AB and CD pair), since cross-domain analogies rely on mapping of more abstract relation(s) than within-domain analogies. Henceforth, as Green et al (2010), discussed cross-domain analogies may require harder evaluation, which was also supported from the involvement of left-sided inferior frontal gyrus.

Sub-processes of Analogies

The process of analogy making can be broken into five, slightly different sub-processes (Kokinov, & French, 2003). They are *recognition* (building a representation), *retrieval* (re-captures the 'base' for the analogy), *mapping* (the 'base' to the target), *transferring* (re-location of the unmapped elements from the 'base' to the 'target') and *evaluating* (certifying if the inferences are suitable).

Recognition is about how context-appropriate and adjustable representations are build, i.e. when describing a target of a source. The *retrieval* process concerns recapturing of similar features, structures

or objects from the base to the target domain. The retrieval concerns also relations. *Mapping* is about mapping mechanisms, when, exploring and finding which elementals of the base do correspond to those of the target (Kokinov & French, 2003). This one is definitely a critical sub-process for the analogy-making (Gentner, 1983). *Transferring* shows how the new knowledge can be in truth implemented into the target. According to some researchers, this sub-process is a part of the mapping henceforth, it is not recognized as an independent one. The *evaluation* sub-process, on the other hand, is a one which has been least investigated upon. It regards the confidence strength, meaning, when one has more or less second thoughts or doubts, establishing the possibility of the transferred knowledge to be suitable for the target domain. Not-rarely at all, this process is assigned to either transfer or mapping. The latter is compatible with the Green's et al (2010) suggestion that cross-domain analogies require more relational intergration, eanbling the mapping and evaluation than the within domain analogies.

One way to differentiate mapping from evaluation is provided by the the 4-level model of A:B::C:D analogy presentation of Sternberg (1977; 1996):

a) Zero information at the entrance (called C-0 cue phase);

b) 1 element is shown **A:**; encoding of 1 element (cue phase C-1);

c) 2 elements are visible **A:B**; encoding of 2 elements and 1 relation (cue phase C-2);

d) 3 are visible **A:B :: C**; 3 elements, and 2 relations (C-3 cue phase);

Sternberg believed that during each cue phase the participant would be able to complete a bit of the component processes, i.e. in C-1 one encodes one element; C-2 one encodes 2 elements and could make a relational inference. The last condition (i.e. C-3), is actually, where the mapping starts, i.e., presentation of C**:** element marks the beginning of the mapping. Sternberg was confident that the components are "*independent and additive*": presentation of **A:B** requires encoding and presentation of A:B::C: need encoding *and* mapping. The C-3 cue phase may enable mapping between the domains, but not evaluation, since the D term is not present and analogical mapping cannot be acompliched, hence, evaluated.

Experiment

Earlier in the text it is shown that Green et al, (2010) go into research of the verbal pair word analogies of the type A goes to B as C goes to D (A:B :: C:D). In the research, cross-domain (far) and within-domain (near) analogies are the subject of interest with an important difference being added. That is the introduction of neuroimaging, regarding the brain areas, that could be affiliated with both analogical types. An example for far analogies, would be Tongue:Taste :: Antenna:Signal. Taste is an abstract,

specific function of the tongue, and antenna is a receiver-giver of signals of any kind. The relations between each of the two couples are specific, and are from different fields. On the other hand, an example for near analogies would be “Kitten:Cat :: Puppy:Dog”, where the relation is a close one. As the fact that they are derived from the same area (cat and a dog are both animals, which can and are, domesticated; and kitten and puppy are their small ones, baby versions), that is why they are called within-domain.

Green et al, (2010) used both types of analogies to try to find or allocate which areas of the brain are more sensitively activated. That is when participants are facing these types of analogies, and which areas are more dormant. Cross-domain (far ones) analogies could require more attention and cognitive reserves, than the within domain ones, they are going to be recognized slower and with much more incorrect answers. That is because the Working Memory (WM) will be more on high alert, needing to call, remember and compare the amount of information that came at the surface, and all needs be simultaneous. That is why, usually, near analogies are easier to deal with, as in to be recognized and pointed out, than far ones (Green et al, 2006a; 2008, 2010). Henceforth, mapping but not recognition of relations is difficult, meaning that if participants start to map relations across domains they should dwell more.

Therefore, in this case, a difference can be anticipated concerning the encoding time for condition four (A:B :: C:) as per Sternberg’s method, compared to the first three conditions (O:; A:; A:B;). This is anticipated, because in this condition, the coding of the second word couples begins and apposition as a process is starting. This is the condition where all that is necessary for the task to be more challenging and burdensome for the participants is visible. Logically, a longer encoding time for this condition should be registered, when it is compared to the other three conditions, but this time should be even longer for the far compared to near analogies. While Green et al (2010) study is of neuroimaging nature, this is a simple behavioral one and uses the 4-level method of presentation of Sternberg (1977), whereas Green shows to the participants, the entire analogical pair at once.

Goals

To check whether analogical mapping poses difficulties for far compared to near analogies. The aim of the experiment is to test if the encoding time for the first three elements, i.e. A:B :: C: will be longer for far analogies than near ones. Since, there are all necessary prerequisites for the mapping process to begin, such result is anticipated.

Hypothesises

Encoding time for coding the three elements from the far analogies (i.e. A:B :: C:;) will be longer than the same operation with near analogies. Such difference is not to be expected when it comes to the other, first three conditions, where 1. Zero, 2. A:, 3. A:B; are being displayed.

Method

Design

The design was a 2x4, within-subject one.

The Independent Variables are two: type of analogy and way of presentation, with different sub-levels.

The First Independent Variable has two levels, according to which the analogies are either near (within-domains) or far (cross-domains), being derived from different semantic areas.

The Second Independent Variable is the type of presentation, of the analogical word-pair couples, presented through the method of Sternberg (1977). The method was already discussed in the beginning, but shortly again, it is: a) Zero information at the entrance; b) 1 element is shown A:; c) 2 elements are visible A:B; d) 3 are visible A:B :: C:. After that the participants clicks “next” so the whole analogical word-couple to be shown.

The Dependent Variables are Encoding time, which marks the time from which the specific elemental is shown (0; A:; A:B; A:B :: C:;) at the entry, until the very instant when the button “next” is being pressed. Accuracy (includes correct answers) and Response time (how fast the participant indicates if the word-pair couples are analogical or not, measured from presing next button, after the initial presentation of 0/A/AB/ABC elements and until response) were also measured.

Participants

All together 95 participants (22 males and 73 females) with average age for males is M = 24, and for females is M = 23.5) took part in the experiment. Subsequently, almost all of them were students from the New Bulgarian University and participated either for credits or just on good will. All of them were right handed and Bulgarian native speakers.

Stimuli

Two pre-tests with word-pair couples were done and were later used in the main experiment. The original used stimuli, in Green et al's (2010), research, were translated into Bulgarian, and modified where it was necessary, so that participants could understand and make their decisions upon them. The stimuli word-couples were then divided into two separated files and a pre-test in semantical diversity and analogical difference, which the participants had to evaluate, were conducted.

The word pairs were a total of 160 as follows: 80 of them *cross* domain and 80 for *within* domain. They were divided into two different files, which the participants had to evaluate. A 7-point scale was used for that purpose, as 1 being "not semantically identical at all" to 7: "entirely semantically identical". Between some of the word-pairs, the difference between Mean and Standart Deviation has variated (from 1 to 3 points). They were excluded from the study. This difference could be explained because of the big spatial difference between the words themselves, as in a complementary word from the within or cross domain. The Mean for the far analogies is M = 4.10 and SD = 1.73, and for the within-domains is M = 5.38 with a SD = 1.48. The difference in the Mean is: 1.28.

An additional questionnaire was made which included only 94 word pairs (47 near and 47 far) of the 160. The question posed this time was about "How analogically to each other are the word pairs bellow*?*". The "*semantic"* was replaced with "*analogical".* The participants were less this time, only 24.

The mean for the analogical test for cross-domains is M = 4.27, with a SD = 1.64; and differed again from the mean for within-domains: M = 5.75, with a SD = 1.33, and this time it was a little higher than the within ones. The difference between the cross-domains Mean for semantic and analogous was small, as was the one between the within-domains. In the end, the final word-pairs were chosen from the analogical pre-test.

An example for near analogy from the experiment is: "Table:Cover :: Floor:Carpet", and for far analogy "Table:Cover :: Nobleman:Mantle".

Each base pair has two targets – one close and one far as in the Green's study (Green et al, 2010). That allows counterbalancing of the near-far analogies across participants, so that all participants could see the same base A:B pairs, but with different near and far targets.

Procedure

Finally, 32 analogical pairs (16 far and 16 near ones), were chosen. Also, 32 false (fillers, non-analogical) pairs were created and added to the experiment (i.e. "Volcano:Lava :: Sleep:Awakening").

Each participant was invited separately into the laboratory, and then inside a small booth with a computer and two chairs inside. Before going indoors, each participant had to fill a paper with consent

which stated that he/she agrees to take part in it and therefore receives one credit point for his/hers seminar's requirements. No phones or devices were allowed inside.

The analogical task itself, was the following: word-pair analogical couples from *the A:B :: C:D* type, in which those pairs were either far or near analogies, and false as a balancing feature were included. They were shown by Sternberg's (1977) 4-level method of presentation. The experimenter gave each participant a quick explanation in addition with a short example, regarding what could they expect from the task itself. The example was the following: "*The cat goes with meowing just as the dog goes with barking*". The incomplete analogical pairs would appear differently, such as, first they might see just element *A***:** which is the "*Cat*", and have to press "next" so that the last part of the word couple is disclosed. It could be that they are presented with the first three elements *A:B :: C:;* which corresponds to "*Cat:Meowing :: Dog:*", etc. After when they have clicked "next" button and the whole analogy is visible, only then could they decide on pushing either "Yes" or "No", evaluating the couple to be true or false. Before starting, the example with the *cat* and the *meowing,* was repeated again to make sure they have understood.

There was a training session before the veritable word-pairs were presented. The analogical task itself was no longer than seven-eight minutes, depending entirely on the participant, which had to do a speeded button press (via an E-Prime button box), to continue forward with the task. Participants were asked to respond as fast and accurate as they could.

The four types, of stimulus presentations can be seen in *Figure 1*, below. Stimulus presentation was randomized for each participant. The stimuli were, additionally counterbalanced for their type of presentation across participants.

Results

Green expects far analogies to be mapped slower with numerous mistakes than the near ones, because they are taken from different semantical fields. His stimuli were used and translated; and worse accuracy and response time is expected to be registered for the far analogies. When it comes to the *encoding* time of 4th condition (A:B :: C:) it should be slower compared to the first three conditions (0:; A:B; A:B :: C), because then the mapping process should start.

When the data was gathered, the formula "M+/- 2SD", was used, and 247 trials out of 3040 for the Encoding time were cut (8.1 %). The afterwards data that remained – correct answers (Accuracy), Response time and Encoding time - was analyzed by mean of condition.

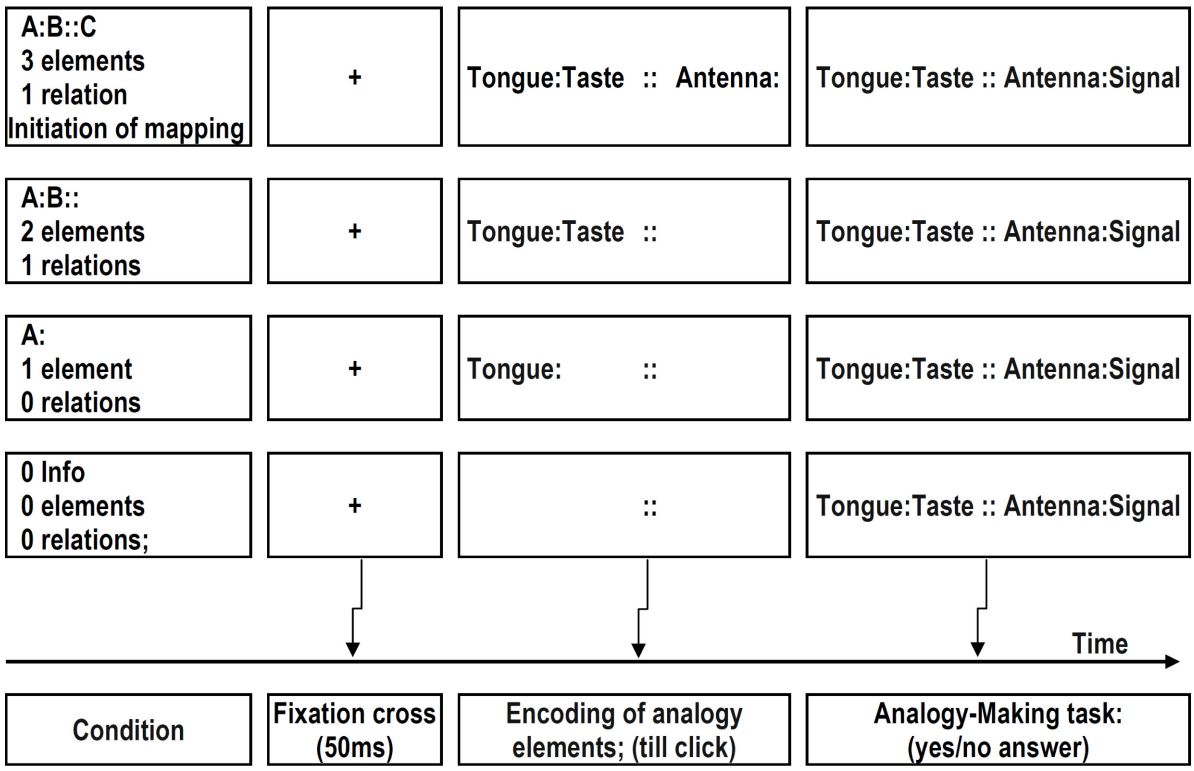

Figure1. Timeline of the analogical task performance

Manipulation check for differences between far and near analogies

As Green et al (2010), hypothesis states, far analogies should be more difficult than near ones, because they are derived from divergent semantic areas, they would require more cognitive reserves, since higher attention is to be required and for the Working Memory's function, too. The below collected results support that accuracy and response time for far analogies do worsens than for near ones, and supports Green's findings.

A 2 (near and far analogies) x 4 (presentation of *0; A; AB; AB:C:*) Repeated Measure ANOVA analyzed the results for accuracy and response time.

The table below shows the Means, Standart Deviations for accuracy for each condition for far and near analogies.

Table1. Mean and Standart Deviation for accuracy of near and far analogies by condition:

Accuracy by condition	Mean	Std. Deviation	Accuracy by condition	Mean	Std. Deviation
Far_0	.85	.204	Near_0	.97	.089
Far_1	.82	.225	Near_1	.96	.127
Far_2	.82	.211	Near_2	.97	.088
Far_3	.86	.211	Near_3	.95	.121

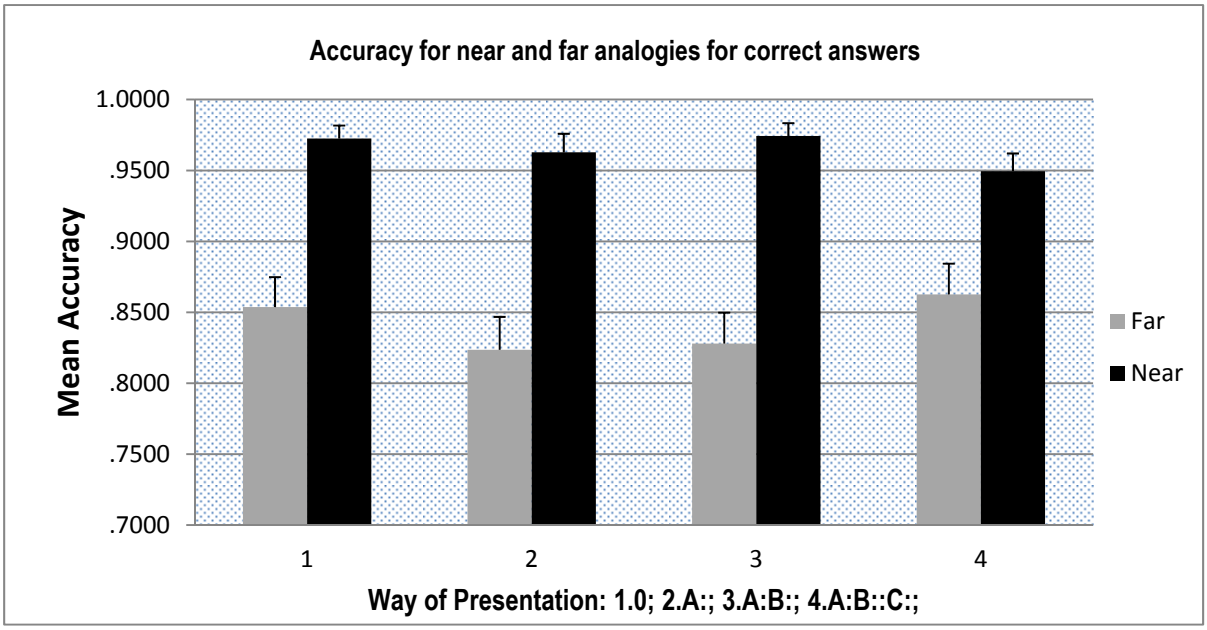

Figure I. It shows the main effects on the type of analogies and the way of presenting them upom accuracy.

Overall, participants were more accurate in identifying the near (Mean accuracy, M = .97) than the far analogies (Mean accuracy, M = .84). Main effect in the analogy type was discovered, being the following: F (1, 93) = 100.383; p = 0.001; and there was no main effect for the way of presentation, F (1, 91) = .441; p = 0.724 (Figure I). Lastly, no interaction between both factors was detected: F (1, 93) = 1.545, p = 0.208.

The Mean and Standart Deviation for Response time for near and far analogies, by condition, is shown, in Table2.

Table2. Mean and Standart Deviation for Response time by condition, for far and near analogies.

RT by condition	Mean (ms)	Std. Deviation	RT by condition	Mean(ms)	Std. Deviation
Far_0	4059.41	1263.29	Near_0	3345.62	1151.14
Far_1	3876.59	1959.08	Near_1	2853.12	988.75
Far_2	3617.20	1394.81	Near_2	2674.85	969.20
Far_3	3073.59	1754.02	Near_3	2300.21	1264.90

As was expected Response time for the correct identification of the near analogies (M = 2793.45) was significantly lower (participants were faster), than for the far analogies (M = 3656.70). The results show: F (1, 93) = 111.553, p = 0.001. Further, for the way of presentation of the analogy couples, also a main effect was found (i.e., F (3, 91) = 19.250, p = 0.001), which indicates a gradual slow dawn in response, when follows A:B::C, A:B, A, and 0 elements presentation. Consitent with the Stenbergs original findings, people made their decisions slower if they were given less information during encoding phase (Figure II), meaning that they most probably have processed the encoding information as was instructed instead of waiting the whole analogy to be visible. This important observation gives as the opportunity to consider encoding time as a meaningful dependent variable for further analyses.

As it was expected, with respect to Sternberg's findings, the amount of information for encoding increases and respectively the amount of information remaining for final processing decreases, as the Response time for correct answers also decreases. Participants were able find the analogies faster if they received almost all information beforehand, i.e. they were shown the base A:B pair and the C element of the target before AB::CD presentation. On the contrary, they were slower if they did not received anything at the beginning, i.e. just a blank screen and then were shown the AB::CD analogy.

Which is in consistent with Sternberg (1977), he also receives a gradual decrease in the Response Time. There is no significant interaction between the two factors (i.e., type of analogy and the way of presentation): F (1, 91) = 1.149; p = .334 (Figure II).

These results are consistent with findings of Green et al (2010), which state that slower response time can be expected from participants, when far analogies are concerned. So we can safely proceed with testing the main hypothesis, namely that the difficulty of the far compared to near analogies is exactly in the mapping phase, rather than in their encoding or evaluation.

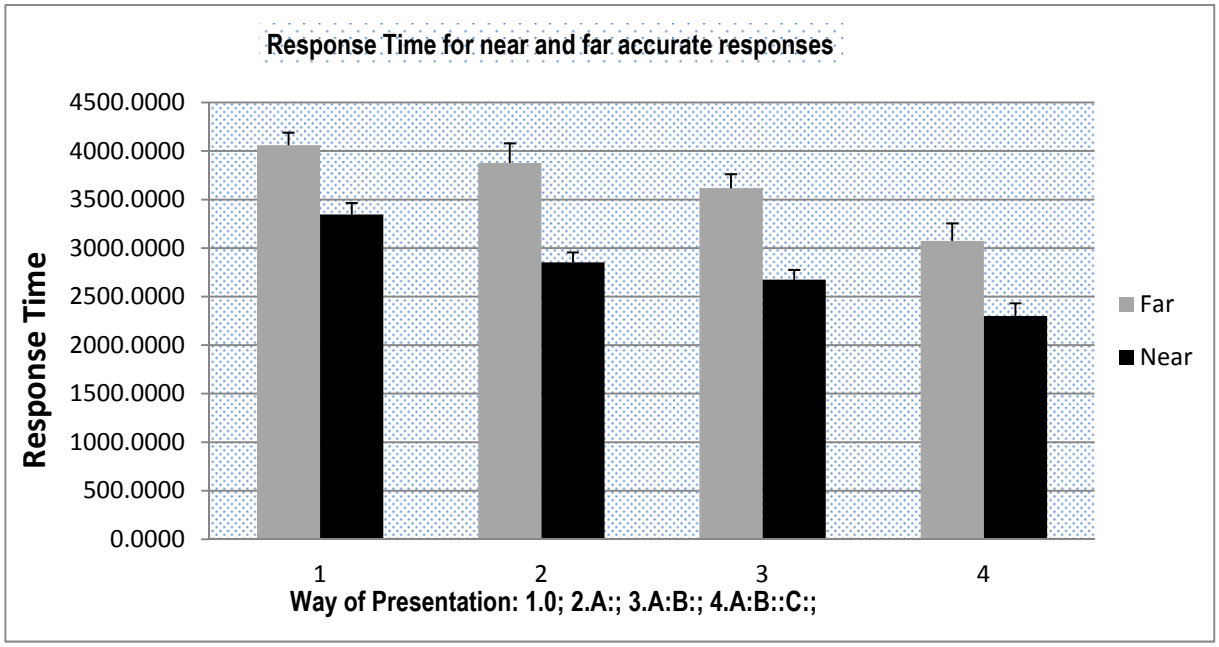

Figure II. It shows the Response time for near and far accurate responses, until participants had to click the "Yes" button.

Results obtained for the Encoding Time

The next results concern the main hypothesis and show the *Encoding Time*. This is the measurement time from the beginning of the trial until the participant clicks the "Next" button and the whole analogy becomes visible. According to this Hypothesis, a difference is anticipated to appear for the *encoding* time, when mapping starts in the 4th condition (A:B :: C:) between the far and near analogies, but not in the other three conditions (0; A:; A:B). A 2 (near and far analogies) x4 (presentation of 0; A; AB: AB:C) Repeated Measures Anova was again used for the data analysis. In Table 3 the Mean, Standart Deviation for Encoding time, for each condition for far and near analogies, are shown:

Table3. Mean and Standard Deviation for Encoding time for near and far analogies, by condition

ET by condition	Mean (ms)	Std. Deviation	Accuracy by condition	Mean (ms)	Std. Deviation
Far_0	736.97	291.46	Near_0	742.11	337.74
Far_1	834.77	349.25	Near_1	834.89	327.59
Far_2	1141.20	559.10	Near_2	1099.41	483.39
Far_3	1449.30	552.29	Near_3	1416.35	507.03

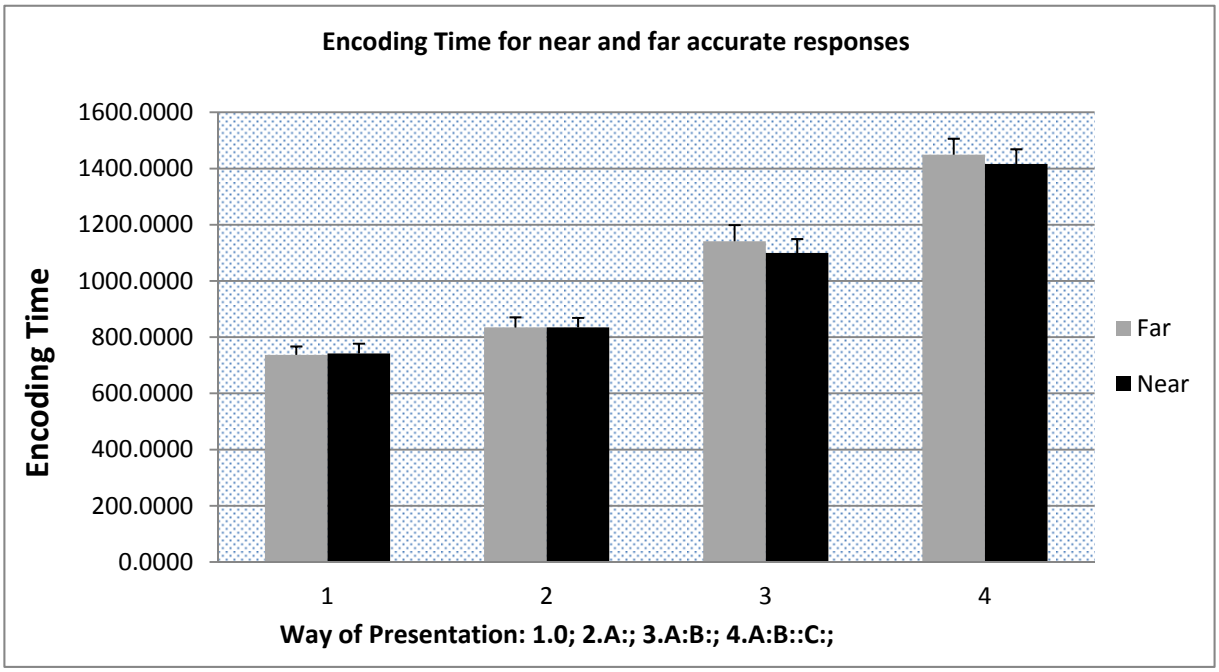

Figure III. Shows the Encoding time for type of analogy with the Standart error values.

The registered mean for Encoding time for near analogies (mean Encoding time, M = 1023.19) is not statistically significant, when compared to far analogies (mean Encoding time, M = 1040.56).

The results show that no main effect was registered for the type of analogy, F (1, 93) = .950; p = .332. Nonetheless, for the way of presentation of the word-pairs there is a main effect: F (3, 91) = 92.497, p =

0.001. Likewise, there is no significant interaction recorded between both factors: F (1, 91) = .429, p = .732 (Figure III).

The hypothesis regarding the *Encoding* time is unconfirmed, due to the lack of any significant interaction between the two factors. Furthermore, the Encoding time for *A:B::C* for near and far analogies was not statistically different from Encoding time of the other conditions. Hence, mapping that may be initiated because of the presentation of the *C* element of the analogy was not statistically more difficult than encoding of *A:B* elements that composed far, compared to near analogies.

Discussion and Conclusions

This study was set out to explore, additionally, the process of analogy making, when one is faced with distant (cross-domain) and close (within-domains) analogies. Green et al (2010), explained the processing differences between near and far analogies with the cognitive demands of far analogy mapping compared to near ones. For that reason the analogy presentation was conducted via the 4-term pairs type: *A goes to B as C goes to D (A:B :: C:D),* which were presented with the 4-level method of Sternberg (1970). If the mapping sub-process of analogies was more cognitively demanding than mapping of the near analogies (Green et al., 2010) than *encoding* time for the 4th condition *(A:B::C:)* should be slower for the far compared to near analogies. However, such differences between A:B::C encoding time of far and near analogies were not obtained, although the far analogies were identified slower and with more mistakes than the near ones, as was expected. Therefore, since far analogies were more difficult than near ones, but no differences for the type of analogies were found, with respect to the condition where analogical mapping was enabled. The evaluation, rather than mapping of analogous of far compared to near pairs may be considered to be responsible for the delayed answers reported in the Green et al's study, (2010).

Evaluation, in analogy making is the final sub-process, where one has to make a decision, whether one is confident in the validity of analogy. The bigger the confidence the stronger the evaluation, and no additional time is wasted on wondering on "what if". In the current experiment there was no condition which showed the whole analogical pair and then to have to click "yes" or "no". So it is difficult to say that evaluation, rather than mapping of the far compared to near analogies slows down the response, but at least the mapping seems to be less probable candidate for explaining the difficulties with far analogies and the heightened recruitment of the prefrontal brain areas, reported in Green et al, (2010).

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