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Sustaining Relational Preference in a Repeated Relational Match-to-Sample Task in the Absence of Task Support

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Abstract

Previous work has demonstrated that relational preference in the Relational Match-to-Sample task can be improved compared to baseline by providing people with the opportunity to consider the target item in isolation prior to receiving the full triad. However, it remains unclear whether the benefits of these supports persist in their absence, or can be observed when a prior strategy has already been established to complete the task. To this end, we conducted two experiments using 2 (presentation-type) by 2 (order) mixed designs to examine the efficacy of two previously established task supports: isolated-focus and description. The aims of this work were to gain further insight into the utility of these supports as a means of promoting relational preference both when the supports are present and when they are absent. We discuss the implications for pedagogical practices and extensions of this work to other materials and tasks.

Keywords: relational cognition; abstract reasoning; relational match-to-sample (RMTS); analogy

Introduction

The ability to recognize and understand abstract similarities and patterns is a crucial aspect of higher order cognition and relational thinking. Relational reasoning has long been regarded as a fundamental ingredient to general intelligence (Spearman, 1904). In fact, common intelligence measurements like Raven's Progressive Matrices (RPM) (Raven, 1938) and the Cattell Culture Fair test (1973) are tasks designed to gauge abstract problem solving. Likewise, in the domain of artificial intelligence, abstract reasoning ability has been argued to be the penultimate measure of a system's robustness and flexibility (Chollet, 2019; 2020).

For decades, cognitive psychology research has been building a case for the importance of relational cognition in everyday life with findings indicating that higher-order abilities like metaphor and analogy (Gentner, 1983; Murphy, 1996), novel problem solving and transfer (Gick & Holyoak, 1980, 1987; Honke & Kurtz, 2019; Kurtz, Boukrina, & Gentner, 2013; Snoddy & Kurtz, 2021), relational category and concept learning (Gentner & Kurtz, 2005; Kurtz, Miao, & Gentner, 2001), and creativity (Dumas, 2018; Dumas, Schmidt, & Alexander, 2016) all in part rely on making coherent connections between seemingly dissimilar cases. Additionally, many of the key concepts that students will encounter in the classroom are

relational in nature and require going beyond the surface-level features to obtain mastery— which appears to be the end goal of virtually all academic endeavors (Goldwater and Schalk, 2016). To make the previous points concrete, consider the following example: a bear, an owl, and a praying mantis share very few physical attributes with one another; nevertheless, they all belong to the same category. In this case, category membership is not defined by overlapping interconnected feature structures (e.g., four legs, dense fur, sharp teeth, muscular build, etc.), but rather by a common relational structure (e.g., X preys on Y). We know this category to be called *predator*, and given the independence of the relational structure from individual attributes, it allows us to use this category in a more flexible way than a category like bear. For example, we need not be limited to members of the animal kingdom when using the category predator, as we also can invoke that category when describing companies which draw success from acquisitions or agencies and individuals who exploit others through manipulation and excessive force.

Much of the theoretical work surrounding relation cognition has been aimed at understanding the circumstances in which people are able to successfully recruit and engage their relational abilities and under what circumstances they are not. In cases where people seem to have difficulty making relational judgements, it begs the question what can be done to decrease this difficulty. This subfield of research has led to the realization of a number of general principles which seem to influence relation and analogical reasoning. One such area of work has demonstrated that comparison of multiple cases can support the recognition of a common relational structure shared among them (Gentner, 2005; Kurtz et al., 2013; Markman & Gentner, 1993; Patterson & Kurtz, 2016, 2020). Another area of work has shown that language can be leveraged to drive participants towards making relational judgements (Christie & Gentner, 2014; Loewenstein & Gentner, 2002, 2005; Ratterman & Gentner, 1998; see Gentner, 2016 for review). For example, Christie and colleagues (2007) demonstrated that applying an arbitrary label to the target item in an unsupervised or “ambiguous” Relational

Match-to-Sample Task (RMTS)¹ led to higher rates of relational responses in children and adults compared to when no such labeling manipulation was applied.

More recently, an investigation by Mason and Kurtz (2023) set out to improve relational responding in RMTS by reducing the attentional demand and guiding the participants' focus to individual items in isolation prior to receiving the full triad. Across three experiments it was repeatedly shown that conditions which utilized the *isolated-focus principle*² as a relational support lead to greater preference for relational matches than baseline comparison conditions which involved giving the participants all of the items at once as is standard in the RMTS. Somewhat surprisingly though, one such experiment showed the most minimal version of isolated-focus that was tested (participants received the target item alone for 6 seconds before receiving full triad) produced nearly equivalent rates of relational preference as a much more intensive and semantically rich description task (participants received the target item alone and provide a written description of it before receiving the full triad). This result indicated that a more demanding task does not necessarily lead to greater preference for relations when leveraging the isolated-focus principle. This might suggest that the more minimal task should be preferred given that it could be easier for instructors to deploy and requires less work on the students end. However, one thing that remained to be seen was how well those results generalized if those supports were no longer present.

Present Study

The present study had three main goals: 1) to further replicate the prior findings that isolated-focus based conditions promote greater relational preference than the baseline RMTS set-up, 2) to examine whether or not isolated-focus based conditions lead to sustained relational preference at an elevated rate when the support was no longer present, and 3) to see if the minimal version of isolated-focus and the description condition produced the same pattern of results. To this end, two experiments were conducted that were greatly inspired by the methodology of Mason and Kurtz (2023). In each of the two experiments, a 2 (presentation-type; within-subjects) by 2 (order; between-subjects) mixed design was deployed, comparing the baseline RMTS with an isolated-focus based condition both when the baseline task presentation was received first and when the isolated-focus based task presentation was received first.

¹ The RMTS task is used to gauge sensitivity and preference for relational content in the presence of compelling object based alternatives. Typically, RMTS utilizes 3-item triads, but larger arrays have been used as well (see Hochmann et al., 2017)

² The *isolated-focus principle* refers to directing attention to valuable information in isolation without distraction, with the goals of encouraging enhanced depth of processing, and a greater likelihood that a structured representation of that information will be constructed.

Experiment 1

This experiment compared two within-subject conditions using the RMTS task: Baseline → Isolated-Focus and Isolated-Focus → Baseline. For this experiment it was predicted that in the Baseline → Isolated-Focus condition participants would show significantly greater preference for relational matches in Phase 2 (Isolated-Focus) compared to Phase 1 (Baseline). However, in the Isolated-Focus → Baseline condition, it was predicted that participants would show a sustained, heightened rate of relational preference. These predictions were motivated by the supposition that when participants experience the baseline task set-up, the attentional demand produced by seeing the full triad simultaneously leads to unsophisticated comparison opportunities between the target item and matches at the time of response—ultimately resulting in relatively more object based judgments. Isolated-focus is meant to correct this by allowing the participants to properly encode the target item in a way that allows for a more relationally rich construal of the item to be used at the time of response. We suspect that if participants have had the opportunity to experience isolated-focus first, that they can carry the strategy and knowledge gained in phase 1 over to phase 2.

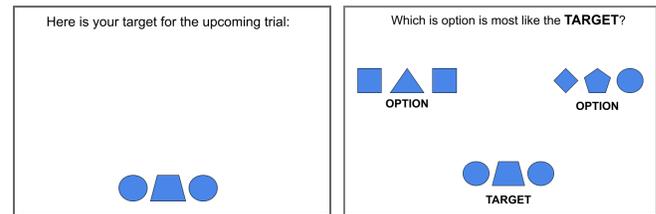


Figure 1: (LEFT) Baseline task presentation for RMTS with a target item (bottom) relational match (upper-left) and object match (upper-right). (RIGHT) Isolated-Focus task presentation with only the target item shown.

Method

Participants

A total of 58 undergraduate students from Binghamton University participated for partial credit toward a course requirement. Participants were randomly assigned to the Baseline → Isolated-Focus ($N = 30$) or Isolated-Focus → Baseline ($N = 28$) conditions.

Materials and Design

Participants were presented with a total of 18 randomized RMTS triads on a computer which were divided evenly into two 9 trial phases. Each triad consisted of three items arranged in a triangular format: a target item, a relational match, and an object match. Each of the constituent items was made of three simple, vertically symmetrical geometric objects arranged horizontally (see Figure 1). All items were light blue with black outline. The objects in the target items and relational matches were arranged in such a way that resembled an ABA pattern and were meant to embody the

relation of symmetry. The object matches did not share this relation, but rather shared one (1Match) or two (2Match) objects with the target item. These shared objects could either match in the corresponding place (MIP), and match in noncorresponding places (MOP) (Goldstone, 1994). The target item was displayed at the bottom-middle part of the screen, while the relational and object matches were displayed opposite of one another in the upper-left and upper-right parts of the screen.

Procedure

This experiment was programmed in JavaScript and delivered via web browser. Prior to beginning the task, both conditions received an identical set of instructions. They were told that they would see a series of item arrangements on their screen and that they would have to select the option that was *most like* the target item. Participants were not informed about the nature of the item arrangements, nor did they receive any training. There was no feedback on their response because there were no correct or incorrect answers. Therefore, their responses were meant to reflect their preference rather than a learned rule.

Each condition consisted of two phases, with the name of the condition representing the version of the task that was used in each phase. The Baseline task presentation was meant to resemble the standard way in which the RMTS task is usually administered. In these phases participants were presented with a prompt to prepare for the upcoming trial for 6s. Participants then received a full 3-item triad, including a target item (labeled “TARGET”), relational, and object match (both labeled “OPTION”), and were asked “Which of these two options is most like the target?” The Isolated-Focus task presentation differed in that instead of a preparation prompt, participants received a target item alone in isolation for 6s and were told that would be their target for the current trial. Participants then received the rest of the triad and were prompted for a response. Once participants in both conditions had finished their first 9 trial phase, they saw another set of instructions which told them that they would be doing the task again and that it would look different the second time, but that their objective was still the same. For their second phase they were given whichever task presentation format they had not already experienced.

Results and Discussion

The purpose of the experiment was: 1) to replicate the prior finding that the Isolated-Focus task presentation facilitates a greater preference for relational matches, and 2) to assess whether that enhanced preference for relational matches persists when the support is no longer present. Overall, the Baseline → Isolated-Focus condition ($M = .59, SE = .48$) and the Isolated-Focus → Baseline condition ($M = .56, SE = .49$) produced similar rates of relational preference (see Figure 2). Likewise, we did not see much of a difference between Phase 1 ($M = .58, SE = .49$) and Phase 2 ($M = .57, SE = .48$) which we did not anticipate. The critical evaluation was a two-way ANOVA performed to analyze

the effect of condition and phase on relational preference. The two-way ANOVA revealed that there was a statistically significant condition by phase interaction ($F(1, 12) = 39.08, p < 0.000$). Simple main effects analysis showed that neither condition nor phase had statistically significant effect on relational preference ($p = 0.399; p = 0.899$). Post hoc comparisons using the Tukey HSD test indicated that relational preference in both the Phase 1 – Baseline ($M = .50, SE = .50$) and Phase 2 – Baseline ($M = .46, SE = .50$) groups were significantly lower than relational preference on both the Phase 1 - Isolated-Focus ($M = .66, SE = .47$) and Phase 2 – Isolated-Focus groups ($M = .68, SE = .47$). The Phase 1 and Phase 2 Baseline groups did not significantly differ from one another and the same was true for the Phase 1 and Phase 2 Isolated-Focus groups.

In summary, this experiment replicated the prior finding that showed Isolated-Focus facilitates higher rates of relational preference compared to Baseline in the RMTS task. However, we did not see any sustained enhancement of relational preference when the Isolated-Focus support was no longer present. Rather, we observed that participants’ preference for relational matches was primarily influenced by the task presentation that they were currently experiencing. In other words, their prior experience with one task presentation did not carry over across phases and influence later responses when another task presentation was utilized. On one hand, this outcome is desirable because it shows that we can increase preference for relations and alter a participant’s response set after they have already had experience establishing an approach to the task and materials. On the other hand, if we start participants with an arguably more desirable task presentation, like Isolated-Focus, whatever benefit they have earned when first engaging with the task may be lost in the absence of that support.

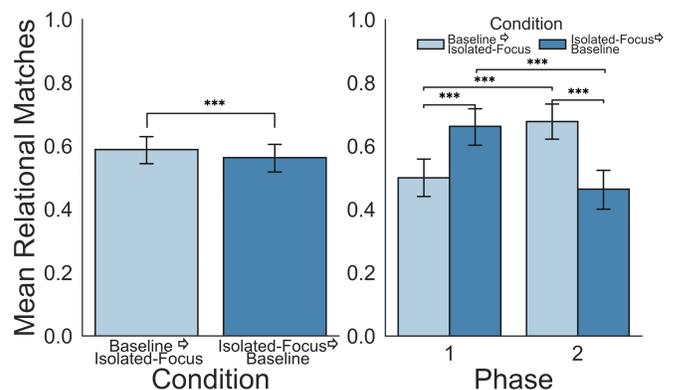


Figure 2: (LEFT) Mean proportion of relational matches by condition. (RIGHT) Mean proportion of relational matches by condition and phase. Error bars represent 95% confidence intervals.

Experiment 2

This experiment directly built off of the results of Experiment 1 and also compared two within-subject

conditions using the RMTS task: Baseline → Description and Description → Baseline. Here, we are using the description task from Mason and Kurtz (2023) instead of Isolated-Focus (see Figure 3). We chose this task presentation specifically because while the two did not differ in aggregate in prior work, they are conceptually distinct and the semantic richness of the description task might make it a more viable option in this particular investigation. Not only does the description task require directed processing of the target item to provide a description, the description that is provided may actually help build a structured representation of the target item and thus lead to a more robust relational construal to bring to bear at the time of response. The predictions for this experiment were much like those of Experiment 1. That is, it was predicted that in the Baseline → Description condition, participants would show significantly greater preference for relational matches in Phase 2 (Description) compared to Phase 1 (Baseline). Though we failed to observe carry over effects in the Isolated-Focus → Baseline condition in Experiment 1, it was predicted that participants in the Description → Baseline condition would show the sustained, heightened rate of relational preference that was originally expected.

Method

Participants

A total of 67 undergraduate students from Binghamton University participated for partial credit toward a course requirement. Participants were randomly assigned to the Baseline → Description ($N = 34$) or Description → Baseline ($N = 33$) conditions.

Materials and Design

As in Experiment 1, participants were presented with a total of 18 randomized RMTS triads evenly divided into two 9 trial phases. The materials and trial structure was identical to Experiment 1.

Procedure

This experiment was also programmed in JavaScript and delivered via web browser. As described in Experiment 1, prior to beginning the task, both conditions received an identical set of instructions. They were told that they see a series of item arrangements on their screen and that they would have to select the option that was *most like* the target item. Participants were not informed about the nature of the item arrangements, nor did they receive any training. There was no feedback on their response, because there were no correct or incorrect answers. Therefore their responses were meant to reflect their preference rather than a learned rule.

Each condition consisted of two phases, with the name of the condition representing the version of the task that was used in each phase. The Baseline task presentation was meant to resemble the standard way the RMTS task is usually presented. In these phases participants were

presented with a prompt to prepare for the upcoming trial for 6 sec. Participants then received a full 3-item triad, including a target item (labeled “TARGET”), relational, and object match (both labeled “OPTION”), and we asked “Which of these two options is most like the target?”. The Description task presentation was much like the Isolated-Focus task presentation from Experiment 1, except the participants had to enter a written description of the target item in a textbox on screen before receiving the rest of the triad and being prompted for a response. When they submitted their description it was removed from the screen. Once participants in both conditions had finished their first 9 trial phase, they saw another set of instructions which told them that they would be doing the task again and that it would look different the second time, but that their objective was still the same. For their second phase, they saw whichever task presentation they did not already see.

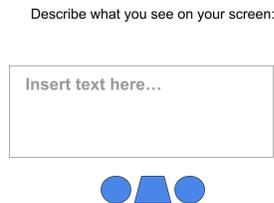


Figure 3: Description task presentation with only the target item shown.

Results and Discussion

The purpose of this experiment was: 1) to replicate the prior finding that the Description task presentation promotes a higher preference for relational matches than baseline, and 2) to assess whether that enhanced preference for relational matches can persist across phases when the description support is no longer available. Across conditions we saw that Description → Baseline ($M = .62$, $SE = .48$) drove greater preference for relational matches than Baseline → Description ($M = .55$, $SE = .50$) (see Figure 4). Unlike in Experiment 1, when looking at the two phases, we observed higher relational preference in Phase 2 ($M = .62$, $SE = .49$) than Phase 1 ($M = .56$, $SE = .50$). A two-way ANOVA was performed to analyze the effect of condition and phase on relational preference. The two-way ANOVA revealed that there was not a statistically significant condition by phase interaction ($F(1, 12) = 0.25$, $p = 0.62$). However, simple main effects analysis showed that both the condition and the phase had statistically significant effects on relational preference ($p = 0.015$, $p = 0.03$). Post hoc comparisons using the Tukey HSD test revealed that unlike the pattern observed in Experiment 1, there was not a significant reduction in relational preference when participants moved from Phase 1 – Description ($M = .60$, $SE = .49$) to Phase 2 – Baseline ($M = .65$, $SE = .48$), but rather a trending, but nonsignificant increase. Crucially, there was significantly higher preference for relational matches in Phase 2 – Baseline compared to Phase 1 – Baseline ($M = .52$, $SE = .50$). All other comparisons were nonsignificant.

In this experiment, our predictions were partially supported, but perhaps in a more nuanced way than we had originally expected. First, while we saw that for Phase 1, the Description task presentation produced greater relational preference than the Baseline task presentation, this difference was not significant, as prior work has shown. However, in contrast to Experiment 1, we were able to show that receiving the Description task presentation in Phase 1 allowed participants to move on to the Baseline task presentation in Phase 2 with a sustained level of relational preference. This can be taken as evidence for the Description task providing participants with an opportunity to construct a more robust relational construal of the target item which makes them more resilient to reverting to object based judgments when the relational support is no longer available to them. This point is further reinforced by the significant difference in relational preference between Phase 1 – Baseline and Phase 2 – Baseline. Participants were able to recognize and value the relationally similar items to a greater degree in the Baseline task presentation after first receiving the Description task. This is the most prominent finding of this experiment given that we did not see any carryover effects in Experiment 1.

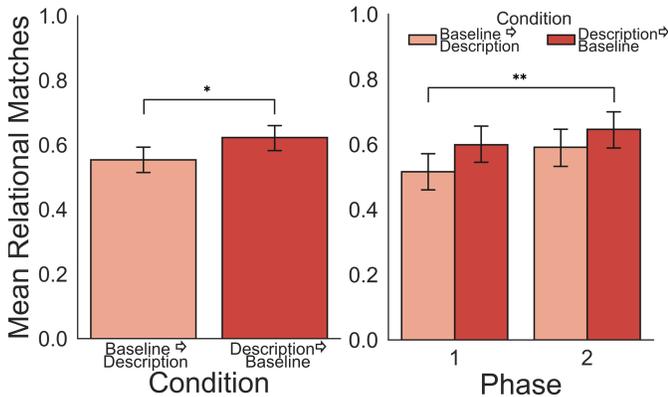


Figure 4: (LEFT) Mean relational matches by condition. (RIGHT) Mean relational matches by condition and phase. Error bars represent 95% confidence intervals.

General Discussion

The aims of the present study were to further replicate prior findings that isolated-focus based conditions lead to greater relational preference than the baseline RMTS task presentation; secondly, to examine whether or not isolated-focus based conditions could lead to sustained relational preference at an elevated rate when the isolated-focus based support was no longer available to participants, and finally, to see if the minimal version of isolated-focus and the description condition would produce the same pattern of results. To this end, we gained useful insights about the strengths and limitations of RMTS task supports based on the isolated-focus principle. We learned that the minimal version of isolated-focus, which involves no accompanying task, continues to be effective in

promoting relational preference beyond “baseline” levels. However, there appears to be a caveat, in that this benefit to relational preference may not be portable—participants were generally not able to sustain heightened levels of relational preference upon reverting back to the Baseline task presentation in Experiment 1. Therefore, the results suggest that minimal isolated-focus may be better suited for drawing attention in the moment to relational structure at the time of encoding. Importantly, we saw that the Description task better prepared participants to continually value relations at a heightened rate when that support was no longer present. This may be explained by the benefits to relational and analogical reasoning that have been shown to be linked to the use of relational language (Gentner & Loewenstein, 2002; see also Vendetti et al., 2015). The description version of isolated-focus may be better than minimal isolated-focus at encouraging sustained relational preference because the act of describing the target invites the opportunity to build a structured representation of that item that is not tied to the specific objects that appear on the screen on any given trial. In other words, with description the relation is explicitly announced rather than more passively encoded.

This work builds on the results of Mason and Kurtz (2023) by revealing an important difference between description and isolated-focus in a way that could not be observed in the prior work. We now see that while description is not a clear cut winner over isolated-focus at driving relational preference, it does appear that the two supports are distinct enough to suggest different use cases. For example, if your goal as an educator is to encourage students to attend to and value relations at the time they are introduced without necessarily needing to train them or instruct them or give them an additional task to complete, then isolated-focus appears to be a highly desirable task support. Especially if there is no immediate following test phase without the task support, isolated-focus may be preferable over description given its relative ease to implement and lightweight nature for both the instructor and the student. However, if your plan is to encourage the construction of more portable and robust representations of the relational content, incorporating item based descriptions into isolated-focus may lead to more relational judgments later on in an environment where there is no task support. The materials that this support task may be most suitable for are those that contain some underlying structure or pattern that is not tied to surface level features. For instance, when students are learning statistics or algebra, they often need to leverage a more symbolic understanding of the material in order to uncover the underlying relationships.

Another insight we gained from our data, that replicated across both of the present experiments, was that our adult participants showed modest levels of relational preference on average. In fact, across both experiments Phase 1 – Baseline groups chose relational matches only about 51% of the time, which really is not a preference at all. This might not be what one would expect from adults on a task like this

given some of the prior developmental and theoretical work on relational thinking. In a RMTS task with simple geometric shapes and a simple relation like sameness or symmetry, one might anticipate that adults would be close to ceiling (see Christie et al., 2007). While, we are not entirely sure what the reason is for the overall lower level of relational responding (e.g., online experiment, 3-object items, monochromatic stimuli, etc.), taken at face value the results suggest that adults, while in many cases superior to younger developmental groups, can be somewhat miserly in expending cognitive resources and engaging the high-level relational abilities they possess. It can be argued that in a task where there is no right or wrong answer, we could expect people to be at a chance for choice preference. However, adults often appear to be adept at locating relations and abstract commonalities and valuing them over more shallow perceptual ones. Perhaps these data help to illustrate how compelling and salient object and feature based similarity can be, and why work that aims to promote sensitivity to relational similarity is so important.

Future work should seek to understand and formalize the mechanisms which give isolated-focus based support of their efficacy. This may be possible to achieve using methods like eye-tracking to examine behavioral differences in saccades when different task presentations are utilized. Further, the work with isolated-focus has yet to be applied to more complex relations and educationally relevant materials. Investigations demonstrating that isolated-focus can be an effective classroom tool would be great contributions to the fields of relational cognition and the science of the learning given the ease of implementation and low demand placed on both educators and students.

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