Strategies of coding and processing in a physical same-different-task[1]

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Abstract

The theory of Memory-guided Inference *explains the representation of seemingly redundant information as useful to obtain economy in a more encompassing representational scheme. Likewise, task execution can have seemingly redundant steps, which subserve economy requirements in a wider context. Visual patterns related by geometrical equivalence transformations instantiate the concept of seeming redundancy in particularly striking ways. These patterns form equivalence sets of different sizes. In* same-different *tasks where patterns related by equivalence transformations were judged as same, reaction times (RT) for all pairs depend on the number of items in their equivalence set. Participants, instead of comparing the presented stimuli directly, search the sets for matching items. In conditions where* same *judgments disregarding equivalence were required, a subgroup of slow responders still displays set size effects, whereas the more faster ones do only partially. The results are seen as evidence for a - seemingly redundant - coding of visual patterns in reference to their equivalence set.*

The interplay of visual structure and task demand is subtle and intricate. However, most of the literature still focuses only on one of these components. This chapter is based on the framework of the *Memory-guided Inference* (MGI, cf. Geissler & Puffe, 1983; Geissler, 1987). MGI specifies processing strategies as a function of task-related representation of object information in perception and memory. Thus, the MGI approach addresses both aspects, task and stimulus characteristics and their interaction.

Processing models developed on the basis of MGI do neither assume a minimal sequence of operations for accomplishing a specific task at hand, nor a minimal information load representing object information in memory. Instead, the representational format is assumed to be subject to rules suitable to cope with large classes of object structures and tasks. This implies that performance cannot be optimal in each case. Several variants of this phenomenon which was referred to as *seeming redundancy*, has been demonstrated in reaction time experiments (Buffart & Geissler, 1984; Geissler & Puffe, 1983; Geissler, 1985; Geissler, Klix & Scheidereiter, 1978; Lachmann & Geissler, 2001).

A special case of seeming redundancy is involved when stimuli form transformationally related sets which, as a consequence, are coded in memory as groups, for example by reference to common prototypes. In several experiments (Geissler & Lachmann, 1996, 1997, Lachmann & Geissler, 1999; Lachmann, 2000; Lachmann & van Leeuwen, 2001, Lachmann & Geissler, 2001) a *same-different* comparison of successively presented 5-dot-patterns was required. The patterns, first used by Garner and Clement (1963), differ in their symmetry and thus in the degree of invariance according to reflection and multiples of 90°

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rotations (*R&R* transformations). As a consequence, with respect to this *R&R* transformations, the patterns belong to equivalence sets of different size.

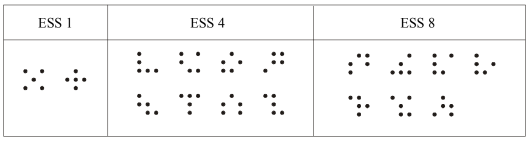

Figure 1. Pattern samples for the 17 subsets first used by Garner and Clement (1963).

There are seven subsets with eight equivalent elements (set size = 8). The eight elements of each of these subsets are equivalent because they can be transformed into another by using rotation & reflection. Eight sets have four elements and two sets do not have any transformational alternative (see Fig. 1). The participants were instructed to respond *same* independent on the orientation of the patterns. Thus, patterns that can be transformed into each other and thus, belonging to the same equivalence set, had to be judged as *same*, and others as *different*. Using such a *categorical* design it was found that RTs of both *same* and *different* responses depend on the equivalence set size (ESS) of both patterns to be compared. This effect occurred independently on the order of presentation. This excludes common model of same-different matching, such as encoding facilitation for good patterns or repeated patterns, to explain the ESS-effect (Clement & Varnadoe, 1967; Pomerantz, 1977; Proctor, 1981; Krueger, 1978; Pachella & Miller, 1976; Biederman, Hilton, & Hummel, 1994; see Lachmann & Geissler, 2001 for discussion). Of special importance is the result that the ESS-effect occurred also when the patterns were identical in shape and orientation (Fig. 2). This excludes mental rotation/reflection of the physical code as the only explanation of the ESS effect (Posner, 1978; see Lachmann & Geissler, 2001 for discussion).

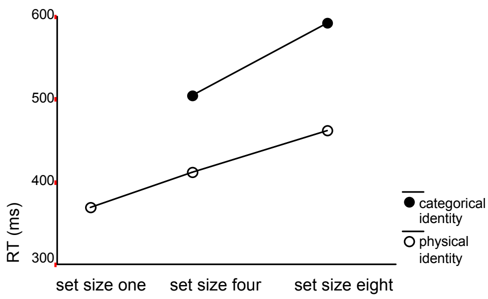

Figure 2. RT (ms) of *same* responses (from Lachmann & Geissler, 2001) as a function of ESS of the sets the patterns to compare belong to. *Physically identical* are patterns that agree in form and orientation, *categorically identical* are patterns that differ in orientation (reflection and rotation).

Memory search instead of direct matching

In Lachmann & Geissler (2001) it is argued that these results support the MGI-approach. The structure of the stimulus set (equivalence sets) and the given task demand (categorical instruction) provokes the system to represented the patterns in memory as task relevant sets. These internal sets are assumed to be searched through in a serial manner (Sternberg, 1966) to decide about the matching of the patterns shown. Lachmann and Geissler (2001) discuss several possible search strategies. The best fit was obtained for a model which assumes a self-terminating search within the one (*same* responses) or the two (*different* responses) activated sets in memory. This search is assumed to start from a randomly chosen element within one of the sets and proceeds serially. When a match has been found for one of the patterns after an average of (ESS+1)/2 search steps, the search for the other pattern can start. If both patterns are represented by the same set, the search starts with a recheck of the element for which the first match was found. In case of physical identity, i.e. patterns are the same in shape and orientation, a second match is found immediately. This amounts to a total of (ESS+1)/2 +1 search steps on average. In case the patterns differ in orientation (but are represented by the same set = categorical identity, excluding physical identity), a second search in the same set has to start. In case of non-identity (*different* responses) a second search in the other set has to be carried out by taking another. In both cases another (N+1)/2 search steps on average are required. Using the ESS of the patterns as a measure for the assumed size of the internally activated sets, theoretical search steps can be calculated as predictors for the RT (Geissler & Lachmann, 1996; Lachmann & Geissler, 2001).

A third processing stage is considering the difference in response generation between physical identity, where a double match provokes a fast decision, and the other conditions. This stage is included in the model predictors by using a free constant *C* for cases where patterns do not agree in both, shape and orientation.

A model fit of R^2 = .98 (p<.001) for the 10 RT has been reached (Lachmann and Geissler 2001) with an optimal *C* = 3.5. It is important to note that this fit includes both *same* and *different* responses. Calculating the response types separately also leads to very good fits ($R^2_{\text{(same)}}$ = .99 and $R^2_{\text{(different)}}$ = .96; *p*<.001). The slope for the function is 20.1 ms and is about equal for both response types (*same*: 20.5 ms; *different*: 17.1 ms).

Task dependency of coding and processing

The results reviewed so far only refer to the categorical instruction, and the model introduced is only developed in respect to that particular kind of task demand. However, what happens in the case of *physical* instruction, i.e. when subjects are to respond with *same* only when the patterns are identical in form and orientation, is also of great interest. The general idea of our model is that the representational format and the processing of that information depend on both the (set) structure of the stimuli and the task demand. It was argued that the role of both components, and especially their interaction, can be proved by using sets of explicitly transformationally related patterns and by using a categorical instruction which defines those patterns as equivalent (i.e. as *same*) which are members of the same set (i.e. which are transformational related). By doing so, the size of the particular equivalence set was used to conclude on the representational format and the way of information processing.

Particularly relevant to the question of how both components (task and set structure) interact, it is important to see what happens when subjects have to deal with the same stimulus set, but with an instruction that does not consider the set structure. One could expect that, in this instance, a set representation (*collective code*) becomes redundant since only the categorical task implies that all elements of an equivalence set are to be considered as equivalent with respect to responding. Instead, feature checking could be assumed. However, comparable experiments (unpublished data from Ackermann, 1986 and from Lachmann, 1996) already give rise to the presumption that ESS still influences the performance when a physical comparison is required, albeit, only partly and in a quite different way.

Checkosky and Whitlock (1973), for instance, found strong ESS effects in a recognition experiment where a physical identity has to be detected between a test target and the items of a previously shown memory set. Lachmann (2000) reanalyzed Checkosky and Whitlock's data and showed that a modified version of the MGI model applies as well for this kind of task (see also Schmidt & Ackermann, 1990).

Geissler and Lachmann (1997) used a physical instruction when they asked their participants to compare the same stimuli by Garner & Clement (1963). They found two distinguishable patterns of performance. One group performed the task showing strong ESS-effects in *same* and in *different* responses, similar to the participants in the categorical experiment. The second group performed generally much faster and showed a weaker dependency on ESS for physical identical patterns, i.e. patterns to be judged as *same*, and no ESS-effect at all for *different* responses. It appears likely that some participants prefer a strategy that is similar to the one obtained under categorical instruction. After reanalyzing the data of this group of subjects, a modified search model can be developed (Lachmann & Van Leeuwen, 2001) motivated by a theoretical, as well as by an empirical fact. Firstly, under categorical instruction, a decision is mainly based on a distinction between categorically identical patterns versus different patterns. According to the model, the RT advantage for detecting physical identity is more or less a "byproduct" resulting from a termination of search, and a quickly triggered response after a double identification in the activated set. For physical instruction however, it is sufficient to detect a physical identity, and there is no distinction between categorical and non-identity needed. Secondly, for this group of participants, there was no significant interaction found between ESS and the types of matching, i.e. the ESS effect is the same for physical, categorical, or non-identity. Therefore, it is assumed that search can always terminate after the identification of one of the stimuli, plus the very first search step for the second. If there is a double identification found at this point, a *same* response can be given after an average of (ESS+1)/2 + 1 steps. Contrary to the categorical instruction, if there is no match found after an average (N+1)/2 +1 steps, a *different* response can be given. Using this model, a satisfying model fit can be reached with $R^2 = .92$ ($p < .01$) for the data published in Geissler and Lachmann (1997).

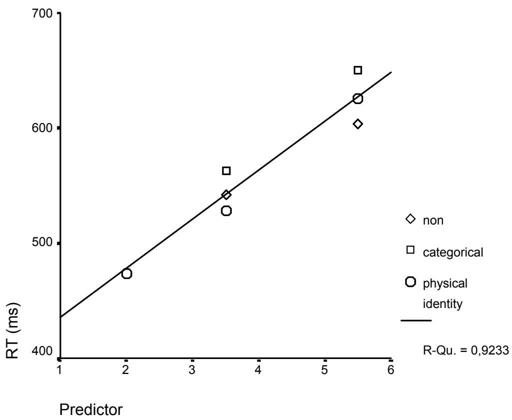

Figure 3. RT (ms) of a subgroup of participants in the experiment reported in Geissler and Lachmann (1997) as a function of the predictors resulting from the search model modified for physical instruction.

The second group of subjects shows a weak ESS effect in *same* responses, and no ESS effect in *different* responses. This group seems to use the advantage of the physical instruction more. Nevertheless, it is assumed that they cannot suppress a *collective coding* either, which enables them to ignore arguments for a *same* response in the case of same shape but different orientation (irrelevant categorical congruence). Therefore, strategies commonly assumed for *same-different* comparison (see Farell, 1985, Sternberg, 1998, or Lachmann, 2000 for an overview) can only be applied when regarding the set structure and collective coding. For instance, in terms of a rechecking explanation (e.g. Krueger, 1978), it could be assumed that for a pair consisting of the same shapes with different orientation, a longer rechecking is necessary to prevent a wrong *same* response. The data suggest a time criterion for the decision to respond *not* with *same*. Theories assuming a decision on the basis of similarity of the patterns (see Reed, 1978 for overview) have to also be translated from feature level to set level as well, for instance, by saying that patterns are most similar when they belong to the same set. Again, this requires a longer rechecking for transformationally related patterns. On the other hand, the fast same responses could be explained by modifying several theories (see Farell, 1985) arguing with the assumption of a fast working identity reporter (Bamber, 1969; see also Taylor, 1976) and a mechanism that is processing (serial or parallel) diverse information available from the stimulus pair more slowly.

Generally, the idea that transformationally related patterns supply arguments for a *same* response, and therefore need more time (likely until a deadline criterion) to be decided to be *different*, while on the other hand physically identical patterns can trigger a fast *same* response, delivers an acceptable explanation for the patterns of results of the second group of participants.

It was shown that the instruction, either physical or categorical, has a very strong influence on the processing of information. Lachmann (in preparation, see also Lachmann, 2000) could show that this is true even when the instruction is varied, using both a blocked and a randomized design within subjects. In one experiment, the participants had to judge the patterns of three sets of size 4 and three sets of size 8 in four sessions with different instructional conditions for each of the sessions, which were counterbalanced between subjects. In two sessions, the physical versus categorical instruction was varied using a blocked design. For the categorical instruction, the results were similar to those obtained in earlier studies, the search introduced model explained the variance in the corresponding RT means very well ($R^2 = .95$; $p < .01$; $C = 2$). For the physical instruction, no distinguishable groups as described in Geissler and Lachmann (1997) were found. The RTs of all participants were much shorter when the patterns were identical (*same*) and much higher when they came from the same set compared with patterns from different sets. Furthermore, there was no ESS effect in negative responses, suggesting strategies as described for the second group above.

In another session, the conditions were varied using a randomized design. A brief stimulus was shown before each of the trials. This stimulus represented the instruction, either categorical or physical for the following pair of patterns. For this condition the pattern of results were almost perfectly identical to the one for the blocked conditions except that there was a significantly higher intercept of about 100 ms. This higher intercept is likely to represent a switch between the coding strategies. This means that even within one session, the stimuli information of a trial is coded and processed depending on the instruction given directly before the presentation. Even the response time of two sequenced pairs consisting of the same physically identical patterns can differ dramatically when the instructional information has been changed. The coding and processing strategy is constant with respect to the instruction. The participants perform the trials in this session as two different tasks.

In a last condition, a blocked categorical design was used again. However, a indicator (cue) was presented before each trial. This cue did not change the instruction. Rather than, the cue offered information about the type of matching of the following patterns. For each trial the probability for *same* or *different* was equal. The cue indicated whether in case of *same* patterns, the matching would be physically or categorically. In comparison to the categorical experiment without cue, an insignificant advantage was found for those trials where the cue points to physical identity. This might reflect different search strategies of the persons. Appart from this, a strong ESS effect was found in *same* and *different* responses similar to the categorical instruction without cue. Also the interaction between ESS and type of matching was found.

It can be concluded that the cue does not lead to a switch of tasks. In this session participants need significantly more time to compare patterns agreeing in shape and orientation than in the session with blocked physical instruction, even though the cue makes it actually dispensable to search for categorical identity.

In an electrophysiological study by Berti, Geissler, Lachmann and Mecklinger (2000), the instruction was varied in two sessions, counterbalanced within subjects using a blocked design. The authors could show that both ESS and the instruction affect the reaction time, as well as electrophysiological parameters such as P300 and slow wave potentials. This strengthens the assumption of a *collective coding* in both conditions. On the other hand, an interaction between the factors suggests that the processing is different in both conditions. Anyhow, the analyses disregarded a differentiation of types of matching. For that reason a model check is not possible. To substantiate whether or not in the data of Berti et al. (2000), two distinguishable groups can be identified, in Lachmann & Van Leeuwen (2001) a reanalysis of the row reaction time data was performed.

For the categorical instruction, a good model fit with $R^2 = .91$ (p < .01) can be reached with interindividually stable effects of ESS for patterns identical in shape and orientation, shape only, and non-matches. For the physical instruction, subgroups were again identified, one performing without ESS effect in different responses, and one (six participants) performing with ESS effects as predicted by the search model (modified for physical instruction, $R^2 = .95$; $p < .01$; $C = 2.8$). It is important to note again that the ESS effect did not differ between *same* and *different* responses. This strengthens the hypothesis of different search strategies depending on the instruction.

Summary

It was shown that the instruction, whether physical or categorical, has a strong influence on coding and processing of information, even when two stimuli are identical in shape and orientation. A collective coding is likely to take place under both, physical and categorical instruction. The matching strategy, however, may be different in both conditions. It was shown that in the physical condition, where *same* judgments disregarding equivalence were required, a subgroup of slow responders still displays ESS effects, whereas the fast ones do only partially. Such strategy effects were also found for visual search and perceptual organization using structured material (Hageboom & Van Leeuwen, 1997).

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