REPRESENTATIONAL ECONOMY, NOT PROCESSING SPEED, DETERMINES PREFERRED PROCESSING STRATEGY

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Abstract

According to Garner, visual patterns are mentally represented as categories rather than by their physical identity. However, physical and categorical identification tasks engender their own specific processing strategies. Nevertheless, categorical strategies should be more generic than physical ones. We tested this prediction using Garner patterns in a same-different task: one version involved categorical, the other physical identification. Both tasks showed effects of categorical representation but also contrasting categorical and physical processing strategies in their response time profiles. When trials from categorical and physical identification tasks were randomly intermixed, mixing costs were additive for categorical trials but not for physical trials, indicating a shift in processing strategy for the latter. For these trials, the physical response time profile was found to be displaced by a categorical profile. We concluded that the more generic processing strategy is the one that maximizes the role of categorical representation.

Gestalt laws, such as *Proximity* and *Symmetry* have shown to be rigid and quantifiable and might, thus, be considered psychophysical laws, i.e. functions of physical properties of our external environment. However, this was not what the Gestaltists had actually in mind. They rather envisaged these laws to reflect a fully internal, psychological principle. This principle was called "Praegnanz" (Wertheimer, 1923), or "Goodness". Goodness was assumed as an intrinsic property of categorical, mental representation, but Goodness is also lawful, i.e., independent of episodic or semantic content. Can this notion be maintained in light of observations that semantic and episodic factors influence perceptual organization and in particular in light of the observation that task-specific attentional sets can lead perceivers to ignore Gestalt factors, including symmetries?

The concept of Goodness has connotations of a pattern being "simple" and "easy to remember". Patterns could possess various degrees of Goodness, and the perceptual system is configured so as to prefer the "best" one. This intuition is notoriously hard to define. Garner (1962) proposed that "good" configurations have few alternatives. Goodness of a pattern, therefore, cannot be evaluated in isolation but only in reference to a set of alternatives, called the *inferred set* (Garner, 1962). This set consists of items considered by the individual as also to be possible to occur in the given situation. Consequently, patterns are not judged by themselves, but are compared against any possible alternatives represented in memory. With this notion, Garner remained close to the original idea of Gestalt psychology; "a pattern, has qualities over and above those which can be specified by designating the physical properties of each element of the pattern." (Garner & Clement, 1963, p. 446). Perception, thus, is an active cognitive process. On the other hand, if the inferred sets were merely the idiosyncratic products of prior experience, it would not be possible to derive any descriptive laws from them. Garner, therefore, assumed that in perception, the inferred set is determined by the dimensional structure of the constituent items. For any given set of stimuli, the inferred set constitutes an invariant representational basis for performance in different situations or tasks.

Garner and Clement (1963) proposed that in specific cases, it is possible to specify the inferred set as the group of objects generated by a transformation operator. An instance is the rotation and reflection (R&R) transformation, and the group it generates is called Equivalence Set (ES). Consider all 90 five-dot patterns that can be constructed on an imaginary 3x3 grid leaving neither rows nor columns empty. They fall into 17 disjunctive Equivalence Sets (ES) of patterns that can be transformed into each other by rotations in 90° steps and/or by reflections. Seven of these ES have eight patterns, eight sets consist of four patterns, and two consist of only one pattern (see Figure 1). Garner proposes that the size of the ES determines Goodness, in the sense that the smaller the Equivalent Set Size (ESS) of a pattern, the larger is its Goodness. Garner and Clement (1963) showed that ESS could in fact reliably predict observers' Goodness ratings.

In a series of studies we used pairs of Garner and Clement's (1963) five-dot patterns in *same-different* tasks (Lachmann & Geissler, 2002; Lachmann & van Leeuwen, 2005a, b). We found strong RT effects for ESS of both the first and second pattern which were presented in succession with a 500 ms interval between them. In Lachmann & Geissler (2002) we proposed a model which allows predicting average RT for any possible pair wise combination of patterns. In this model, we assumed that the ES of both items of a *same-different* pair constitute a representation which can be described as some kind of Sternberg's (1966) memory set. Accordingly, RTs were found to be proportional to the memory set size (Lachmann & Geissler, 2002). This implies that the task was performed by means of a memory search (Sternberg, 1966) of both ES. Lachmann and van Leeuwen (2005a) established that ES search was not affected by the relative frequency of occurrence of individual items and showed (2005b) evidence that search of the ES was performed independently of the criterion of sameness: categorical versus physical identity. One version of the task, the *categorical identity* task (Lachmann & Geissler, 2002) required that pairs that are rotated or reflected versions of each other (member of the same R&R ES) were treated as *same*, the other version, the *physical identity* task (Lachmann & van Leeuwen, 2005b) involved treating them as *different*. Therefore, the categorical task encourages the construction of ES, whereas the physical task discourages it. The fact that ES were used as representation in both tasks implies that this is a generic, spontaneous process, not a process induced by specific task requirements. If the stimulus representations are categorical in nature (ES), the categorical task might be easier than the physical task.

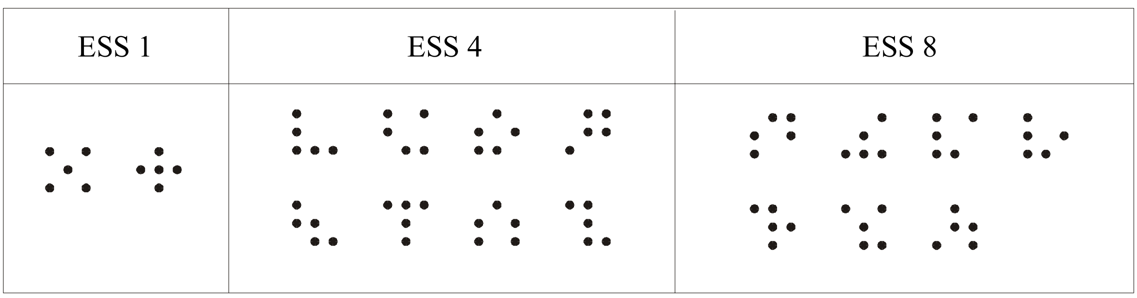

Figure 1. Examples of patterns representing the 17 pattern sets Garner and Clement (1963) introduced as stimuli in Goodness rating experiments.

In Lachmann and van Leeuwen (2010) we tested this hypothesis by providing these two tasks separately, in different blocks of an experiment to the same participants. Even though the categorical and physical tasks both may involve search of ES sets, the search algorithm may differ between them. Thus, an overall comparison of RT across tasks is too simplistic. Specific task requirements may bring about their own specific processing strategies. Categorical and physical tasks show distinct RT profiles across conditions (Lachmann & van Leeuwen, 2005b). Because these profiles differ between tasks, a simple comparison between their average RTs may be irrelevant for the hypothesis that a categorical representation is used in these tasks. If representations are categorical in nature, the more robust strategy should be the one belonging to the categorical task. In Lachmann and van Leeuwen (2010) this hypothesis was investigated by comparing the blocked conditions of both tasks to one, in which the two tasks, physical and categorical, are randomly intermixed. Participants could switch between strategies on a trial-by-trial basis. This would lead to a general delay needed to shift contexts. Such kind of effect has been obtained numerous times in the literature using different paradigms (e.g., Koch, Prinz & Allport, 2005). In Lachmann and van Leeuwen (2010), however, we did not mix two unrelated tasks, but rather two related ones, and, furthermore, the strategy belonging to one task was predicted to be more robust than the other one. We assumed that this strategy transfers without much change from the blocked to the mixed conditions. Thus, we expected a general delay for the more robust strategy. In contrast, for the less robust strategy, we assumed that it would not survive mixing unscathed: Instead, a shift in strategy of this task as a consequence of mixing may occur.

A shift in strategy may indicate that an integrated representation is formed, and that the task is performed in a uniform way between categorical and physical task. A third aim of the study, therefore, was to observe to what extent mixing leads to unification in strategy. In the categorical task, we previously obtained a linear effect of ESS on search time, independently of whether the two patterns of a pair were identical (identity match, IM), were different but from the same ES, and thus could be transformed into another by R&R operations (Categorical Match, CM), or belong to different ES (non-matches, NM). The uniform slopes of the fits for "same" and "different" responses suggest that this task was performed using one and the same process for deciding *same* or *different* (Krueger, 1978). We shall call this the *categorical task profile.* In the physical task, we found linear effects of search times, but with different slopes for *same* (IM) and *different* (NM) pairs. This indicates that different processes are being used for *same* and *different* judgments, respectively (Bamber, 1969). The reason may be that *different* responses are complicated by physical similarity in a physical identity task. Detecting difference is frustrated by similarity between patterns, while detecting sameness is facilitated by it. These effects will interact with ES search: different patterns with small ESS share more axes of symmetry with each other than those with large ESS. According to this as similarity criterion, the smaller the ESS of a pattern, the more physically similar it is to the others in its ES (Garner & Clement, 1963). In other words, when similarity plays a role, it has the same effect as Goodness for *same* and an effect opposite to Goodness for *different* trials. This provided us with an explanation in terms of the representational mechanism, why a two-slope solution was necessary for the physical condition. In support of this interpretation, we found evidence for response conflict: RTs were much larger than in other conditions on CM trials, i.e., patterns from the same set are responded to as "different". The combination of a two-slope fit for the search times as a function of ESS, in combination with the presence of a response conflict we shall call the *physical task profile*. The presence of these different task profiles means that a direct comparison between the mean RT of both tasks may be inconsequential for their categorical representation, as the tasks are executed using different strategies.

In our recent study (Lachmann and van Leeuwen, 2010) we used these profiles in order to investigate whether a strategy is used that normally belongs to a categorical or physical task. In one set of conditions, we presented categorical and physical tasks in separate blocks. We investigated which task takes longer on average and whether we can identify task-specific profiles. Furthermore, we compared these blocked conditions with a condition in which categorical and physical identity task are randomly intermixed between trials. We investigated whether task-mixing costs are additive, leaving the task-specific profile unchanged, or non-additive, suggesting a switch in strategy. We expected additivity for categorical, and non-additivity for physical identity trials. In that case, as a consequence of mixing trials, we expected for physical identity trials a shift from physical to the categorical RT profile, but not vice versa. In a fourth condition we used a categorical task, but information was given prior to each trial whether the following pair was either, with equal probability, a CM or an NM or, again with equal probability, an IM or an NM pattern. In this condition, a physical identity decision was sufficient to correctly perform the task in case of IM. Because of this, even though this condition belongs to the categorical task, participants could, in principle, adopt a physical strategy here. This latter condition was added in an effort to disprove our own prediction, which would succeed if participants chose to shift to a physical strategy when prior information enables that.

Results

In Lachmann and van Leeuwen (2010) we replicated the effects found in previous studies for blocked physical and categorical task conditions. The results, therefore, are consistent with our earlier conclusion that set-representations are task-invariant. ESS effects in the categorical task were found generally more robust than in the physical task. The categorical identity task typically yields ESS effects invariably over conditions, giving rise to uniform one-slope model fits for items that are identical (IM), identical under transformation (CM), and non-matching items (NM). In the physical task, effects of ESS are less robust. As found before, response conflicts occur for CM conditions in the physical identity task, precisely because of their categorical representations. They complicate “different” responses for categorically identical items. Because of this intervening variable, these trials are, as in our previous experiments, excluded from the model fits. Another indication that the ESS effects are less robust in the physical tasks is that, for the remaining IM and NM trials, two-slope model fits are typically required (Lachmann & van Leeuwen, 2005b). In Lachmann and van Leeuwen (2010) a similar difference in robustness was observed when categorical and physical tasks were presented in different blocks: robust and uniform ESS effects in the categorical task, whereas in the physical task the ESS effects were limited to the IM condition; a response conflict was in evidence in the CM condition, and the remaining data required a two-slope fit, including a reversal of the slope sign, even though for the negative slope in the NM condition, the significance test failed to pick up the effect.

Comparing physical and categorical task blocks, the physical task was performed at a faster rate than the categorical one. This might be considered as prima facie evidence against the view that the categorical representations are fundamental to both tasks. However, the dependency of the physical task advantage on type of matching conditions (IM, CM, NM) indicate that there the strategies invoke different types of processes. We have earlier suggested that a one-process sameness detection strategy might explain the results of the categorical task (Krueger, 1978), whereas a two-process model may be more suitable for the physical task (Bamber, 1969). This contrast, or any other contrasting models, would militate against a direct comparison of the overall response times between both tasks.

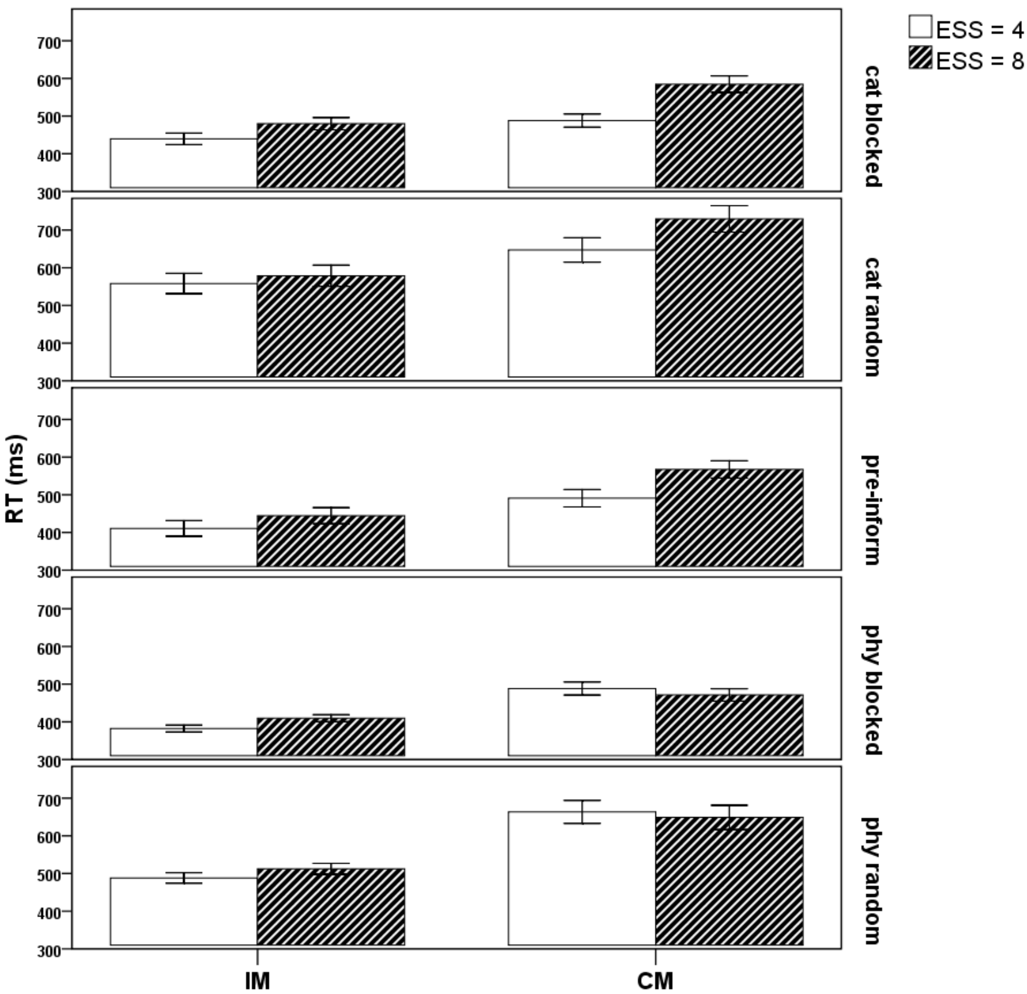

Figure 2. RT (ms) and 5% confidence intervals for Identity Matches (IM) and Category Matches (CM) for ESS = 4 and ESS = 8 pairs in the five task conditions: categorical-blocked (cat blocked), categorical-random (cat random), categorical-pre-information (pre-inform), physical-blocked (phy blocked) and physical-random (phy random).

We investigated whether the categorical nature of the representations should make the categorical identity strategy more robust than the physical identity strategy. When categorical and physical identity trials were randomly mixed, the mixing costs were additive in the categorical task. This suggests that the categorical strategy was not affected by mixing. In contrast, no main effect of mixing was found in the physical task, suggesting that mixing resulted in a shift in strategy for the physical identity task. From this it could be concluded that the categorical strategy was more robust than the physical strategy.

There are various indications in our data that the shift in strategy that resulted from mixing consisted in a move to a categorical strategy. Unlike in blocked conditions, in the mixed conditions ESS effects in the physical identity task were uniform in both IM and NM conditions, resulting in a one-slope model fit normally belonging to a categorical strategy. In addition, the response conflict always observed for the physical tasks in the CM condition was particularly enhanced by mixing tasks. Since this conflict arises from the requirement to respond “different” to items that are same categorically, the larger the effect the more predominant the role of categorical information. This result, therefore, is also consistent with a shift to the categorical strategy. The categorical strategy is preferred, even though the physical strategy is generally faster. A related result was obtained between different processing strategies for letters and non-letters. Letters were processed more analytically than non-letter shapes (Lachmann & van Leeuwen, 2008) but whenever the two were randomly intermixed, a holistic strategy was observed for letters also, if the task allowed it. Even though letter-specific processing is highly automatized, and therefore faster, here, too, a uniform strategy was preferred.

We concluded that perceivers have no interest in minimizing processing time. This observation evokes Geissler's concept of seeming redundancy of processing (Geissler, 1985, 2001, 2004). Why is this seemingly redundant processing route preferred? Perceivers' interest may be in maximizing the stability of their representational system. We may conclude that the preferred processing strategy is the one that is maximally governed by the more enduring, categorical representations. Representational economy, not processing speed, determines preferred processing strategy.

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