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OBSERVATIONS

Separate Features Versus One Principle: Comment on Shimaya (1997)

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In his article "Perception of Complex Line Drawings," A. Shimaya (1997) proposed a quantitative theory that was designed to predict perceived segmentations and amodal completions of line drawings. Shimaya further evaluated the integrative approach of structural information theory (SIT; R. Van Lier, P. Van der Helm, & E. Leeuwenberg, 1994) to pattern interpretation. It is argued in this comment that Shimaya's evaluation of the SIT approach is based on a misconception of SITs basic assumptions and an inappropriate data analysis.

Shimaya (1997) addressed an interesting issue in visual perception that has been the subject of much research in past decades. It concerns the topics of figural segregation and amodal completion in line drawings. It has been demonstrated that both global pattern properties, such as bilateral symmetries (e.g., Boselie, 1988, 1994; Buffart, Leeuwenberg, & Restle, 1981; Sekuler, 1994; Sekuler, Palmer, & Flynn, 1994), and local pattern properties, such as the occurrence of certain junctions (e.g., Boselie, 1994; Wouterlood & Boselie, 1992), may influence perceived interpretations of line drawings. Because of the influence of multiple pattern aspects, attempts to develop an explanatory model on the interpretation of line drawings on the basis of a variety of factors seem to be a priori fruitful.

Shimaya introduced seven separate features (as the author calls them) that could be classified as more or less global or local. These features are relative number of corners, good continuation, symmetry, curvature constancy, convexity, coincidence, and similarity. For each of these features, a metric was proposed to quantify its strength. The author tested the predictive value of the model by means of a paper-and-pencil task on 24 patterns in which 20 participants drew the pattern segments that they perceived. The author concluded that his model was rather successful in explaining the frequency of occurrence of the interpretations. Shimaya's analyses included a comparison with a recent elaboration of the structural information theory (SIT; Van Lier, Van der Helm, & Leeuwenberg, 1994, 1995), which accounts for global and local aspects in figure segregation and amodal completion as well (to be referred here as SIT's integrative approach). According to Shimaya's analyses, the performance of SIT's integrative approach was poorer than Shimaya's model. In this comment, I argue that Shimaya's evaluation of SIT's integrative approach (Van Lier et al., 1994) is incorrect. Therefore, I primarily focus on the analyses and the SIT predictions as such.

In his article, Shimaya highlights an alleged counterexample of SIT (Shimaya, 1997, Figure 18E, 18F and 18G; see Figure 1). In Shimaya's drawing experiment, 19 observers preferred the completion in Figure 1B. This drawing agrees with the impression that most readers will share, namely, two bars, one partly occluding the other. One participant, however, drew a rather anomalous completion (see Figure 1C). According to Shimaya's analyses, SIT would predict this anomalous completion to be more likely than the completion as given in Figure 1B. According to SIT, the opposite is true: Interpretation 1B is predicted to be highly preferred to Interpretation 1C. As I argue, Shimaya's conclusions are exemplary for the way the data were analysed.

I hasten to say that I am the last to claim that there would be no counter evidence against SIT's integrative approach as specified thus far (see, e.g., our own discussions of the approach, Van Lier et al., 1994, 1995). The main point here, however, is that an evaluation of an alternative approach should at least apply an appropriate analysis on the correct version of that approach. In the following, I first give a brief summary of SIT's integrative approach in just enough detail to illustrate Shimaya's analysis. I do not elaborate on the different features in Shimaya's model or on the exact determination of the complexity values in our approach, as the point can easily be made without large theoretical digressions.

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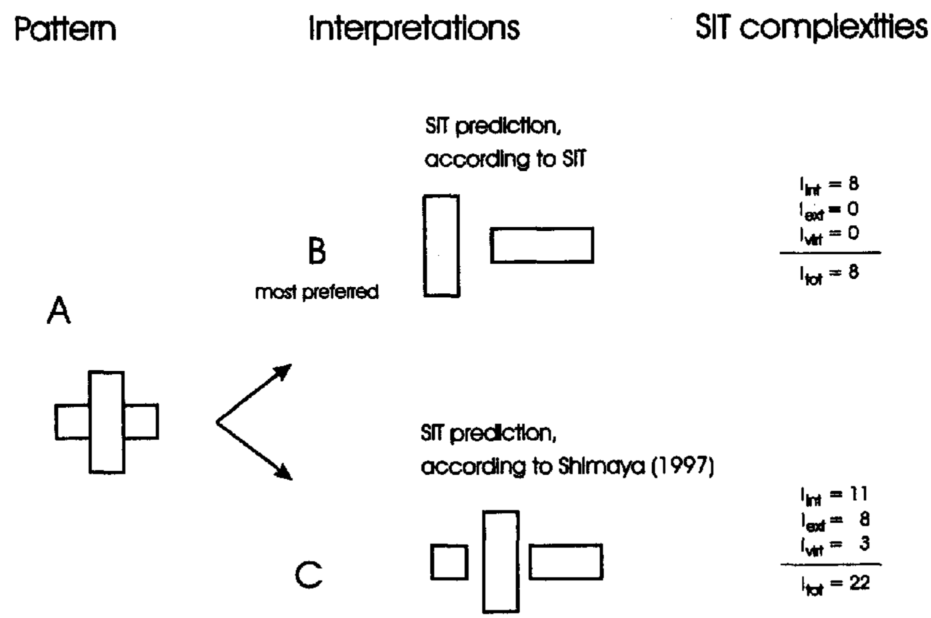

Figure 1. An alleged counterexample to structural information theory (SIT). According to Shimaya (1997), SIT would predict that C is preferred to B. However, as $I_{tot}(B) < I_{tot}(C)$, the opposite is true. int = internal; ext = external; virt = virtual; tot = total.

SIT's Integrative Approach

The key concept of SIT is the minimum principle (Hochberg & McAlister, 1953), which states that the simplest interpretation of a pattern is selected by the perceptual system. To quantify the minimum principle within SIT, a perceptual coding system and a measure of complexity have been developed (Leeuwenberg, 1969, 1971; Van der Helm & Leeuwenberg, 1991, 1996; Van der Helm, Van Lier, & Leeuwenberg, 1992). By means of that coding system, regularities in the pattern are accounted for. In general, the complexity of a representational code is inversely related to the number of descriptive parameters in a code and is expressed in terms of structural information (I). In SIT's integrative approach (Van Lier et al., 1994), the authors have argued that three aspects of an interpretation jointly determine the perceptual complexity of an interpretation: shape, position, and occlusion. They have shown that regularities within the perceived shapes support a specific interpretation, whereas regularities in the relative position of the perceived shapes (more specifically the accidentalness of junctions) weaken that interpretation. They further have demonstrated that the more structural elements of a shape are occluded, the weaker the completion tendency toward that specific shape will be. In this approach, these three aspects are embedded in the internal structure, the external structure, and the virtual structure, respectively. The complexities of these structures can be expressed in terms of structural information (to be referred to as I_{int}, I_{ext}, and I_{virt}, respectively).[1] The authors further have argued that the account of the internal, external, and the virtual structures corresponds, to a certain extent, to three well-known tendencies in the domain of visual occlusion, namely, the simplicity of shape, the avoidance of coincidence, and the good-continuation principle.

A key concept in Van Lier et al. (1994) is the hypothesis that, for a given pattern, the sum of the complexities of the three structures, or the total perceptual complexity (to be referred to as I_{tot}), for the most preferred interpretation is lower than for any other interpretation of that same pattern. This proposal was tested on a large variety of patterns and data stemming from different articles: Buffart et al. (1981), Boselie (1988), and Boselie and Wouterlood (1989). It appeared that of these 144 patterns the most preferred interpretation had the lowest I_{int} in 52% of all cases, the lowest I_{ext} in 65% of all cases, and the lowest I_{virt} in 49% of all cases. Only in 3% of all cases all three structures had the lowest complexity. However, I_{tot} was the lowest for the most preferred interpretation in 95% of all cases.

Considering the alleged wrongly predicted pattern of Figure 1 (Shimaya, 1997, Figure 18E), it appears that for interpretation 1B all complexity values are lower than for interpretation 1C. So, interpretation 1B has better shapes, less coincidental junctions, and fewer occluded elements. These differences are expressed in the respective complexity values (see Figure 1). Evidently, as $I_{tot}(B) < I_{tot}(C)$, SIT predicts interpretation B to be the most preferred interpretation, as opposed to what is claimed by Shimaya.

[1] Note that Shimaya (1997) remarks (p. 39) that I_{int} represents the same measure as applied by Buffart et al. (1981). However, as the authors have mentioned explicitly (Van Lier et al., 1994), this is not the case as in Buffart et al.'s study regularities both in shape and position were assumed to strengthen an interpretation and were accounted for accordingly.

Reconsidering Shimaya's Evaluation of SIT

To evaluate the SIT approach, Shimaya performed a multiple-regression (MR) analysis with the preferences (number of participants) as dependent variable and the three complexity values for each interpretation as independent variables. The MR model in turn was used to predict the number of participants that would choose a given interpretation, this time using the complexity values as predictor variables. In one analysis, the MR model was based on all patterns and actual preferences of 20 participants. In a second analysis, one half of the patterns (the odd numbered patterns in Figure 14 of Shimaya, 1997) and data served to acquire an MR model to predict preferences for the other half (not vice versa). According to the first analysis, the predicted number of participants that would prefer interpretations B and C in Figure 1 were 10.22 and 12.48, respectively. According to the second analysis, these numbers were 9.42 and 17.36, respectively (note that, as these numbers are derived from the MR model, they do not necessarily sum up to the maximum number of 20 participants).

The performed MR analysis on the SIT complexities gives rise to two fundamental objections. The first is that the analysis on the three separate complexity values as done by Shimaya ignores the essential comparison of I_{tot} values. The second is that the MR analysis considers interpattern comparisons, whereas, according to SIT's application of the minimum principle, predictions should be based on intrapattern comparisons. Although both aspects are strongly intertwined, I attempt to focus on them successively.

One, Not Multiple, Predictors

As mentioned, according to SIT's integrative approach, only I_{tot} is considered as a predictor for the preferences. This I_{tot} value reflects the interactive aspect between the three tendencies; a relatively low complexity value on one of the structures allows greater flexibility for the complexity values on the other structures. For example, if an interpretation reveals very regular shapes, the maximum degree of occlusion in which that interpretation is still predicted to be preferred is higher than would be the case if the shapes were less regular. The same could be said for the simplicity of the shapes versus the degree of coincidence, or the degree of coincidence versus the degree of occlusion, etc. However, Shimaya ignores the concept of I_{tot} and treats SIT as a collection of separate features instead of a complexity measure governed by one principle (i.e., the minimum principle). This further guides Shimaya's reasoning about the impact of the SIT complexities on perceived completions, which can be illustrated by means of Shimaya's discussion of the pattern in Figure 2 (Shimaya, 1997, Figure 14, pattern 18). According to Shimaya's drawing experiment, interpretation B is preferred to interpretation C. As $I_{tot}(B) < I_{tot}(C)$ (see Figure 2 for complexity values), SIT would predict interpretation B to be the most preferred interpretation. Yet, Shimaya discusses the SIT predictions on that pattern in the following way (Shimaya, 1997):

> in Line Drawing 18 in Figure 14 [see Figure 2, this comment], for example, I_{virt} was 3 in the interpretation with completion (. . .), whereas it was 0 without completion (. . .). This indicates that completion is unlikely because smaller I_{virt} indicates less complexity. However, the result of the experiment was the opposite: Nineteen of 20 participants chose [the] interpretation with completion. That is why the correlation coefficient of I_{virt} was positive in this analysis, which means that larger I_{virt} indicates less complexity, contrary to what is expected by SIT. (p. 39)

Clearly, what is stated above does not agree with the notions of Van Lier et al. (1994). The authors have never claimed that preference predictions can be made on the basis of the complexity value of I_{virt} alone. As pointed out already, I_{virt} of the most preferred completion could very well be higher than I_{virt} of the second-best completion. Stating it otherwise, SIT even predicts interpretations with higher I_{virt} if it would lead to a lower I_{tot}. In Van Lier et al. (1994, p. 898)—on

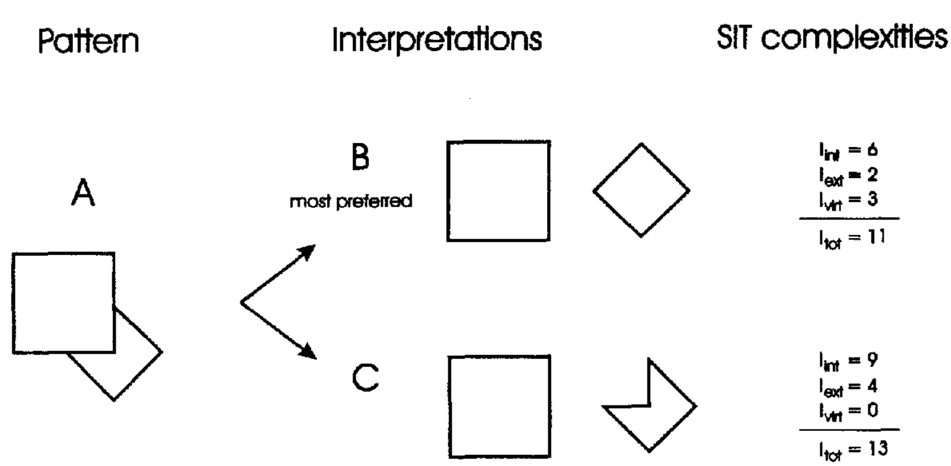

Figure 2. Shimaya (1997) suggests that structural information theory (SIT) would consider interpretation B to be less likely than interpretation C because $I_{virt}(B) > I_{virt}(C)$ (see citation in text). However, as $I_{tot}(B) < I_{tot}(C)$, the opposite is true. int = internal; ext = external; virt = virtual; tot = total.

which Shimaya's discussion of the SIT approach is actually based—the authors have shown that for the most preferred interpretation a higher complexity value for one or two structures is rather a rule than an exception (see, e.g., the percentages correct predictions for the single complexities quoted above). This issue already points at another important aspect that has been neglected in Shimaya's evaluation of SIT, namely, that according to the minimum principle predictive comparisons have to be made between different interpretations of the same pattern (intrapattern comparisons), not between interpretations of different patterns (interpattern comparisons).

Intrapattern, Not Interpattern, Comparisons

As the MR analysis is based on correspondences between separate factors and actual preferences, accidental partial correlations can easily distort the predictions. The likelihood for such accidental correlations further increases with smaller numbers of tested patterns, especially when they are rather similar to each other. To demonstrate this, consider the example in Figure 3. When confronted with pattern A, most perceivers would agree with interpretation A1. Now, suppose that of a sample of 25 participants, 24 participants indeed drew A1 but that 1 participant, for one or the other reason, drew an anomalous completion like A2. As $I_{tot}(A1) < I_{tot}(A2)$ (see Figure 3 for complexity values), interpretation A1 is predicted to be preferred, as one might have expected. However, if an MR analysis, similar to the one of Shimaya, would be performed to predict the preference of this pattern, the predicted preference appears to be highly unstable and to depend strongly on the characteristics and preferences of the other patterns on which the MR model is based. More specifically, it can be demonstrated easily that on the basis of such an analysis even the anomalous completion (A2) can be predicted to be perceived most frequently. I illustrate this by means of patterns and preference data taken from Van Lier et al. (1995, Experiment 1). Patterns B and C in Figure 3 are taken from two different stimulus subsets of Van Lier et al. (1995). According to that study, pattern B is most likely to be completed globally (i.e., the most regular shape, B1) and not locally (i.e., on the basis of linear extensions of incoming contours, B2), whereas pattern C is most likely to be completed locally (C2), not globally (C1). Notice that the local completions have relatively high I_{int} values and low I_{virt}

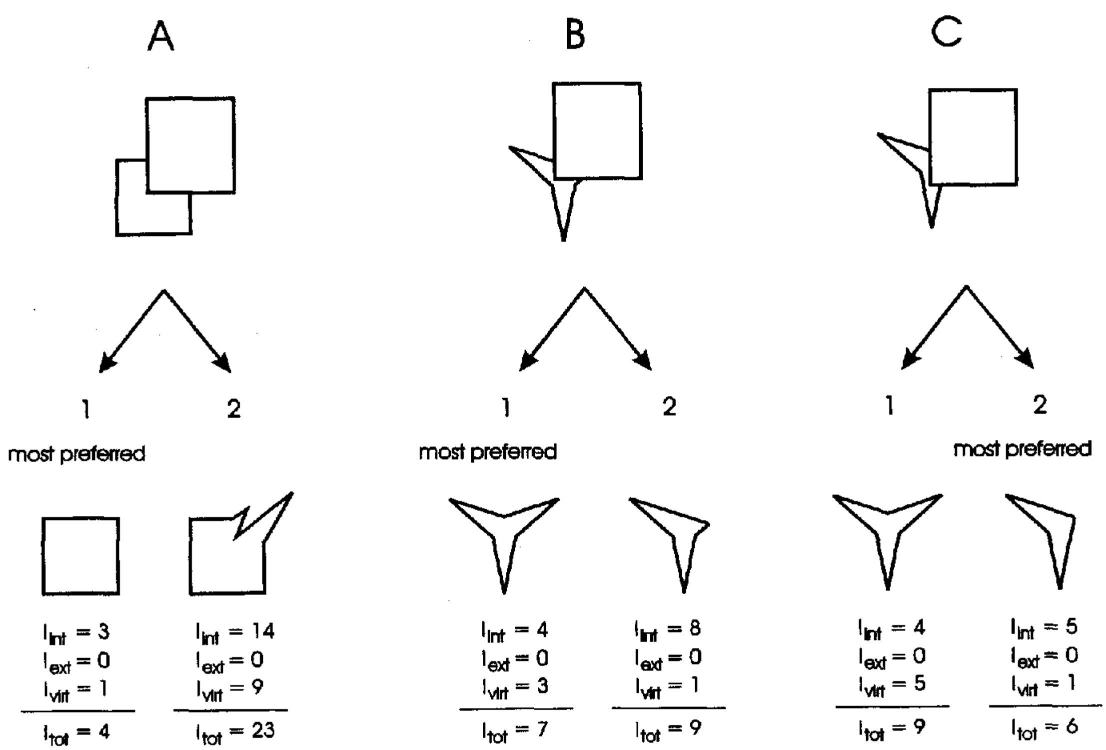

Figure 3. Pattern A represents a rather classic occlusion example in which A1 is the most preferred interpretation and A2 is an arbitrary anomalous completion. Patterns B and C stem from Van Lier et al. (1995). According to that study, B1 is preferred to B2, and C2 is preferred to C1. Each of these qualitative preferences are correctly predicted by SIT when comparing the I_{tot} values of the interpretations of a specific pattern. However, if the predictions are based on a multiple-regression model as was done by Shimaya (1997), then the outcome appears to be highly unpredictable; depending on the subset of patterns that are included in the MR model (B-like patterns, C-like patterns, or both), the predicted most perceived interpretation of pattern A could be either A1 or A2. int = internal; ext = external; virt = virtual; tot = total.

values, whereas this is the other way around for the global completions ($I_{ext} = 0$ for all interpretations). In the following analyses, the likelihood of interpretations A1 and A2 have been estimated by means of different MR models, on the basis of complexity values and preferences of different subsets of patterns (as $I_{ext} = 0$ for all interpretations, only I_{int} and I_{virt} are considered as independent variables). In the first analysis, the MR model is based on just subset 1 of Van Lier et al. (1995), containing pattern B and five similar patterns. Now, if the I_{int} and I_{virt} values of interpretations A1 and A2 are entered as predictors in this specific MR model, then the estimated preferences for A1 and A2 are +57.1% and +75.3%, respectively (note that these percentages do not necessarily sum up to 100%). So, on the basis of this analysis, it would be concluded that the anomalous completion is predicted to be perceived most frequently. In the second analysis, the MR model is based on subset 2 of Van Lier et al. (1995), containing pattern C and five similar patterns. Again, the anomalous completion has a higher preference: +47.5% and +64.9% for A1 and A2, respectively. Finally, in the third analysis, both subsets are included in the MR model. This time, A1 is predicted to be highly preferred to A2: +93.7% and −78.7% (!), respectively. The reason for the large differences (and the odd predictions on A2) lies of course in the set-dependent accidental correlations between the complexity values and the obtained preference data on which the specific MR model is actually based. Such an analysis disregards the fact that specific interpretations stem from specific patterns. That is, interpretations are to be considered as each other alternatives, and may actually compete with each other (causing a pattern's interpretational ambiguity), only if they are evoked by the same pattern. Although it can be said that for larger sets of qualitatively different patterns the MR model is likely to deliver better predictions, an intrapattern comparison of the I_{tot} values for the alternative interpretations of pattern A would have led to a correct and stable prediction.[2,3]

It is not difficult to recognize that similar accidental correlations between separate SIT complexities and preferences affected Shimaya's results as well. Taking all of Shimaya's patterns and interpretations, the values of I_{int}, I_{ext}, and I_{virt} appear to be lowest for the most preferred interpretation of a given pattern, in 83%, 92%, and 4% of all cases, respectively, whereas I_{tot} is lowest for the most preferred interpretation in 96% of all cases. Regarding these patterns (for which a relatively small subset actually evoked completion interpretations), high I_{virt} values generally correspond with high preference values, favoring the odd prediction of Figure 1C. The application of the MR analysis (on unjustly separated SIT complexities) to predict preferences is perhaps even more peculiar as the author acknowledges dependencies caused by the specific stimulus set in the possible outcome of the analysis but seems to justify the usage of the analysis by remarking that the analysis reveals reasonable results on his own model (Shimaya, 1997):

> Note that the number of sample drawings and their variation were limited in this experiment, but the proposed theory still could better estimate the whole set of ambiguous drawings than SIT (p. 40)

Concluding Remarks

This comment was written to put Shimaya's evaluation of SIT's integrative approach into proper place. In conclusion, it can be said that Shimaya's incorrect evaluation of SIT is due to the usage of I_{int}, I_{ext}, and I_{virt} instead of I_{tot}, in an analysis in which the relation pattern/pattern-interpretations is disregarded. Of course, such considerations also have their implications on predictions of Shimaya's model. Because of that, a comparison of the two models concerning their predictive impact cannot be made easily. This does not mean that I do not agree with Shimaya's basic idea that quantitative models on pattern completion would gain a lot if they take into account both global and local aspects of an interpretation. Nor does it mean that I claim that SIT's integrative approach on global and local aspects is above criticism. Actually, in Van Lier et al. (1994, 1995), the authors have discussed several patterns that are not predicted correctly by their approach. No doubt there are various aspects in the approach that need further consideration. For example, the quantification of each of the complexities is still open for further study (Van Lier et al., 1994, 1995). Moreover, other complexity calculations (perhaps including weighing factors for each of the complexities) could be considered as well but are likely to be more complex and would therefore need convincing experimental support (e.g., by way of optimizing the number of correct intrapattern predictions on I_{tot} for large samples of patterns). It should further not be left unnoticed that beside the impact of structural aspects on segregation and completion, metrical aspects may have their influence on the perceived interpretations as well. For the moment, however, we regard SIT's integrative approach as a reasonably successful attempt to combine some well-known tendencies in the interpretation of line drawings.

It is, of course, a great challenge to improve the approach more and more. Indeed, any approach in whatever field of research must be open to critical evaluation. Naturally, such an evaluation must be based on an appropriate analysis on the correct version of that approach.

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[2] Notice that preferences may be influenced by so-called context effects (Van Lier et al., 1995), but it might be clear that the MR analysis on separate SIT complexities is not an appropriate method to account for such effects in terms of SIT.

[3] As preference predictions are to be based on intrapattern comparisons, any further correlational analyses on I_{tot} values and preference data should depart from these intrapattern comparisons.

References

Boselie, F. (1988). Local versus global minima in visual pattern completion. *Perception & Psychophysics, 43,* 431–445.

Boselie, F. (1994). Local and global factors in visual occlusion. *Perception, 23,* 517–528.

Boselie, F., & Wouterlood, D. (1989). The minimum principle and visual pattern completion. *Psychological Research, 51,* 93–101.

Buffart, H., Leeuwenberg, E., & Restle, F. (1981). Coding theory of visual pattern completion. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 241–274.

Hochberg, J., & McAlister, E. (1953). A quantitative approach to figural 'goodness.' *Journal of Experimental Psychology, 46,* 361–364.

Leeuwenberg, E. (1969). Quantitative specification of information in sequential patterns. *Psychological Review, 76,* 216–220.

Leeuwenberg, E. (1971). A perceptual coding language for visual and auditory patterns. *American Journal of Psychology, 84,* 307–349.

Sekuler, A. (1994). Local and global minima in visual completion: Effects of symmetry and orientation. *Perception, 23,* 529–545.

Sekuler, A., Palmer, S., & Flynn, C. (1994). Local and global processes in visual completion. *Psychological Science, 5,* 260–267.

Shimaya, A. (1997). Perception of complex line drawings. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 25–50.

Van der Helm, P., & Leeuwenberg, E. (1991). Accessibility, a criterion for regularity and hierarchy in visual pattern codes. *Journal of Mathematical Psychology, 35,* 151–213.

Van der Helm, P., & Leeuwenberg, E. (1996). Goodness of visual regularities: A non-transformational approach. *Psychological Review, 103,* 429–456.

Van der Helm, P., Van Lier, R., & Leeuwenberg, E. (1992). Serial pattern complexity: Irregularity and hierarchy. *Perception, 21,* 517–544.

Van Lier, R., Van der Helm, P., & Leeuwenberg, E. (1994). Integrating global and local aspects of visual occlusion. *Perception, 23,* 883–903.

Van Lier, R., Van der Helm, P., & Leeuwenberg, E. (1995). Competing global and local completions in visual occlusion. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 571–583.

Wouterlood, D., & Boselie, F. (1992). A good-continuation model of some occlusion phenomena. *Psychological Research, 54,* 267–277.

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