Notes and Comment

The visual specification of events: A response to Ullman

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Ullman (1977), in a reply to an earlier paper in this journal on object identity in apparent movement (Warren, 1977), questioned the validity of the finding that "ecologically transformable" displays were perceived as a single object in motion and "ecologically nontransformable" displays as two separate objects. He produced a wire-frame object which, when viewed from one angle, cast the outline of a square and, after a 5° rotation, cast the outline of a triangle. This demonstrated that the two figures or "phases" of the allegedly nontransformable square-and-triangle display (j) were in fact related through such an object. Hence, Ullman claimed, the principled distinction between ecologically transformable and nontransformable displays was untenable and the original finding simply a reflection of other factors, perhaps timing parameters.

It is obvious that there are many possible objects which have both a square and a triangular projection. Each may be described by a projective group of all the perspectives on that object, each group containing a square and a triangle as members. This fact gives rise to two related questions: (1) Why is display (j) seen as two separate objects instead of one of the many possible objects with a square and a triangular projection? In other words, what makes the display "ecologically nontransformable"? (2) Given a display which is seen as one object, why is it seen as *that particular* object instead of another of the possible objects which also contain the given projections?

In his critique, Ullman has misinterpreted the general claim of the ecological approach to event perception (Shaw, McIntyre, & Mace, 1974; Shaw & Pittenger, 1977) and the claim as it was stated in the previous article (Warren, 1977). The proposal is not that nontransformable displays themselves are ecologically unrelated, but that they will fail to *specify* a unified object under transformation to an observer (see p. 265, paragraph 2). Arbitrarily distant members of a projective group are not necessarily sufficient to specify a continuous object. The fact that they are mathematically related does not mean that they will be perceptually identified

as different views of the same object. In fact, a central problem of event perception is to determine and appropriately characterize the visual information required to specify a certain event. Apparent movement displays which perceptually specify a transformation should have a higher salience than those which underspecify it. Similarly, ecologically significant transformations should have a higher salience than nonsignificant ones, because the perceptual system has been tuned over a period of phylogenetic and ontogenetic time to detect them. However, this does not mean that an individual could not see or learn to see nonecological or underspecified transformations, given the appropriate context, lack of context, or attentional "set." Animated pumpkins do appear to turn into carriages. However, under apparent movement conditions, such transformations should be less salient, more unstable, and more ambiguous.

Addressing the event perception problem, Shaw, McIntyre, and Mace (1974) have proposed that a display which specifies an object's *period of symmetry*, in this case the degree of rotation which brings the object back into congruence with itself, is sufficient for the perception of a continuous object and its shape. In such a situation, it has been argued that the display acts as the generator set for a complete group of perspectives (Shaw & Wilson, 1977), thereby perceptually specifying the intermediate views seen under apparent movement conditions. Hence, to answer the first question regarding when two rather than one object should be seen: When the rotational symmetry period of a possible object is not given, no group of perspectives is specified, and two separate objects should be perceived. Such displays have been called ecologically nontransformable. The possible alternative, the continuous deformation of a rigid object, should have low salience due to its relative ecological implausibility.

In response to the second question regarding multiple possible objects: What is specified by a transformable display is that object and only that object whose symmetry period is given. If additional information becomes available then a more complex object may be specified and perceived. By analogy, a soap bubble spanning increasingly complex structures will preserve a minimal surface area within the given constraints. In this sense, the ecological approach to event perception incorporates a principle of perceptual optimality, a principle not yet fully understood but related to the suggested "principle of

perceptual transitions" (Shaw & McIntyre, 1974) or "adjacency principle" (Gogel, 1978).

The foregoing analysis predicts that we can make a continuous square-into-triangle transformation by adding information which specifies the symmetry period of a complex object which has both a square and a triangle in its group of perspectives. This is essentially what Ullman intimates with his wire-frame figure; the same is possible with a solid three-dimensional object such as a square-based pyramid or a wedge. By interpolating a transitional view of a pyramid between the square and the triangle, the symmetry period of a complex object is given, making the display ecologically transformable. In a brief study, we tested the salience of object identity using three-phase displays in which the interpolated phase either was or was not a transitional view of a pyramid under rotation.

METHODS

The displays were solid black figures inked on a white background (see Figure 1), presented in a Gerbrands three-channel tachistoscope, Model G-1130. Displays a-d were practice displays, e-f were projections of a pyramid under rigid rotation, and g-h were the endpoints (square and triangle) of those rotations with an interpolated phase not specifying any rigid rotation. Recognizing the imprecision in the figures used in the previous study and produced with a shadow-caster (noted by Ullman), projective displays were generated on a NOVA computer. The prototypic square measured 14 mm in diameter and was viewed from a distance of 80 cm, subtending approximately 1° of visual angle. Displays were presented under two displacement conditions, either superposed or separated by 1.5°. To explore the possible interaction of shape and timing parameters suggested by Ullman, all displays were presented in a continuous back-and-forth cycle under four conditions of phase onset asynchrony (POA): 60, 120, 220, and 300 msec.

Five male graduate students were given one trial with each display under each displacement and POA condition. After initial training with the practice displays, the subjects viewed a test display for 15 sec before answering the identity question ("Do you see one or more than one object?"), describing what they saw, and giving a confidence rating for the description on a scale of 1 (low confidence) to 7 (high confidence).

Figure 1. Two- and three-phase displays. Display e specifies a pyramid under rotation through 90°, f through 120°.

RESULTS

The results are summarized across subjects by transformability, POA, and displacement condition in Table 1. The percentage of trials in which subjects reported seeing one continuous object is consistently much higher for transformable than for nontransformable displays. This is the case with both superposed and displaced displays at all timing intervals in which identity was reported, for all subjects. When subjects do report perceived identity on nontransformable displays, the confidence ratings of their descriptions of the event are consistently lower than those for the transformable displays, indicating a lower salience for the transformation.

There are both displacement and POA effects. Perceived identity on transformable displays is a U-shaped function with respect to POA. The phenomenon is more compelling (as evidenced by higher confidence ratings), over a wider range of time intervals, when the figures are superposed than when they are displaced.

Table 1
Percentage of Trials in which Object Identity was Reported, and Means and Standard Deviations for Confidence Ratings of Verbal Descriptions on Those Trials

		Phase Onset Asynchrony														
		60 msec			120 msec			220 msec			300 msec			Combined		
		CR			CR			CR			CR			CR		
		%	M	SD	%	M	SD	%	M	SD	%	M	SD	%	M	SD
Superposed	Transformable	20	4.5	1.50	100	4.0	1.26	90	5.2	1.55	50	6.0	.89	65	4.8	1.53
	Nontransformable	0			70	3.1	1.24	10	2.0		0			20	3.0	1.22
Displaced	Transformable	0			40	3.3	1.79	100	4.6	1.11	40	4.8	1.30	45	4.3	1.45
	Nontransformable	0			0			10	3.0		10	4.0		5	3.5	1.00

Note—Number of trials in each "%" cell = 10. Number of trials in "CR" cells vary with the number of trials in that condition in which identity was reported, indicated by the corresponding "%" entry.

Superposition also had an effect on nontransformable displays at 120 msec, the only nontransformable condition with a nonnegligible percentage of perceived identity. Phenomenological descriptions in this condition reported planar deformations with display (g), with comments such as, "Like nothing I've ever seen before," emphasizing its low ecological significance, and ecological animations with display (h), three of the four subjects who perceived identity reporting a bird flapping its wings. There were occasional reports in other nontransformable conditions of two rather than three separate objects, described as slight deformations or strange rotations accompanied by a second flashing figure. Transformational displays seen as one object were predominantly described as a pyramid under rotation, although there were reports of planar deformation. The dominant reports at 60 msec with all displays were of two or three static flickering objects; nonidentity reports at 300 msec were predominantly of three successively flashing objects.

DISCUSSION

The results demonstrate that a square can be continuously transformed into a triangle if sufficient information is provided in an apparent movement display. When the interpolated figure does not act to specify an ecologically significant transformation, identity has low salience and separate objects are generally reported. Although timing parameters do affect the compellingness and boundaries of the apparent movement phenomenon, the finding holds across all timing intervals tested.

The central assertion is that perception is congruent with the information specified in a display. The use of "transformable" and "nontransformable" refers to the event specified, not to one which is mathematically possible. When the available information is perceptually inadequate or contradictory, the display will be ambiguous, and it is in such impoverished situations that attentional variables become critical in determining a consistent reading of the display. In the displays used here, slight line coverage specifying depth was in conflict

with texture specifying a frontal planar surface, potentially conveying either rotations in depth, elastic deformations in the plane, or unrelated figures. In such cases, either the event with the highest ecological significance will win out or attentional factors will tip the balance. The conflict conditions account for the ability of some subjects to see planar deformations instead of rotations or separate objects; one subject failed to see any of the displays in depth until encouraged after testing.

The questions to be investigated revolve around the conditions under which transformations are adequately specified, and point in a direction opposite that of conventional research. Stripping displays down to minimal figures adrift in empty space will result in a theory based on informational ambiguity and uncontrolled attentional variables, describing a rather capricious system forced to make do without sufficient raw materials. Rather, displays may be enriched, incorporating contextual constraints which are systematically varied until an event is fully disambiguated.

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