Information Concentration Along Visual Contours

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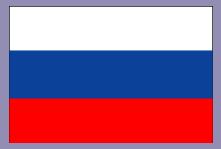
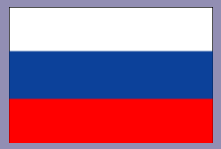
Presenter Information

- *Name & Surname:* Rushan Ziatdinov
- PhD in Mathematical Modeling, Numeric Methods, Program Systems from Ulyanovsk State University, Ulyanovsk, Russia (before 1995 was known as Lomonosov Moscow State University in Ulyanovsk City).
- *Nationality:* Tatar
- *Citizenship:* Russian Federation

Work Experience



- 2006-2010: Lecturer, Assistant Professor at Tatar State University of Humanities & Education, Kazan, Russia;



- 2009-2011: Assistant Professor at Tupolev National Research Technical University (Kazan University of Aviation), Kazan, Russia;

- 2010-2011: Postdoc, Seoul National University (서울대), South Korea;

Work Experience

- January-February 2012: Visiting Assistant Professor at Seoul National University (서울대), South Korea;

- August 2013: Visiting Assistant Professor at Shizuoka University (静岡大学), Hamamatsu, Japan;

- Since 2011: Assistant Professor at Fatih University, Istanbul, Turkey.

Aim of this talk

- Indicating some ways in which techniques of information theory may clarify our understanding of visual perception;
- Explain how an information is concentrated along visual borders;
- Explain the basics of mathematical models used in this approach;
- Presenting some new ideas for scientific visualization.

Visual Perception

- *Visual perception* is the ability to interpret the surrounding environment by processing information that is contained in visible light [Wikipedia].
- *Perception* is an information-handling process [Attneave, 1954]: much of the information received by any higher organism is *redundant*.

Information Concentration

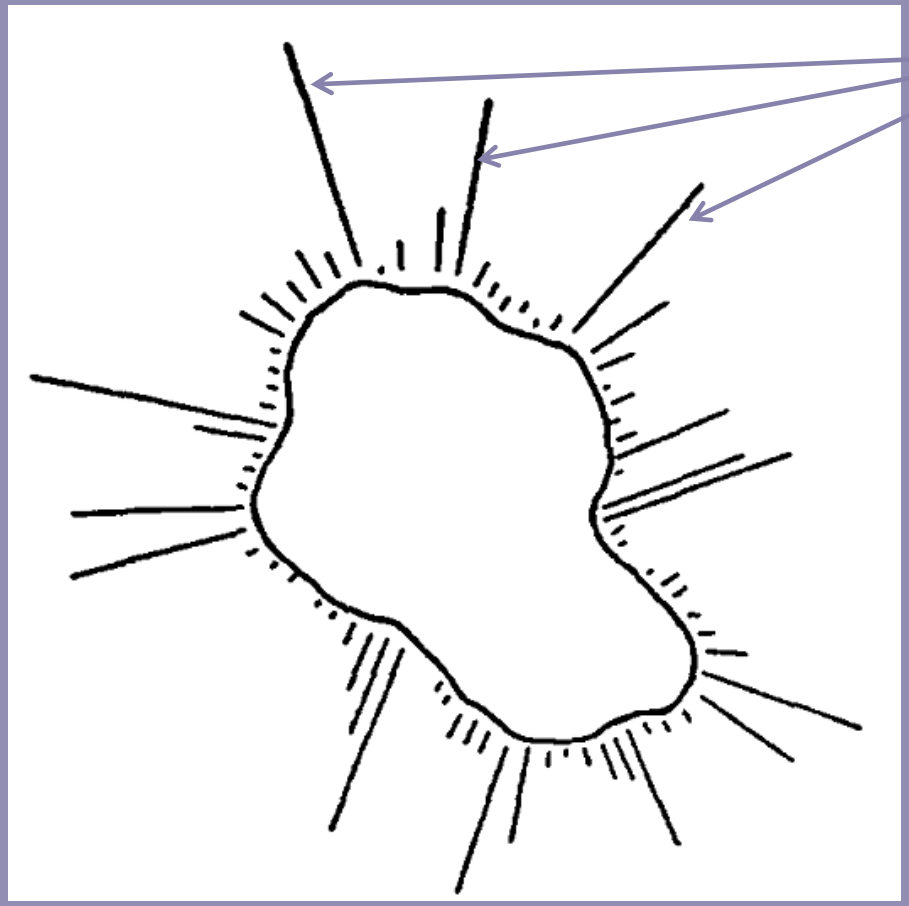
Attneave (1954) notes that it is evident that redundant visual stimulation results from either:

a) An area of homogenous color (color includes brightness here);

b) A contour of homogenous direction or slope;

and is further concentrated at those points on a contour at which its direction changes more rapidly (peaks of curvature).

Information Concentration



Peaks of curvature function $\kappa(s)$
s - arc length

Fig. 1. *Subjects attempted to approximate the dosed figure shown above with a pattern of 10 dots. Radiating bars indicate the relative frequency with which various portions of the outline were represented by dots chosen.*

What is curvature?

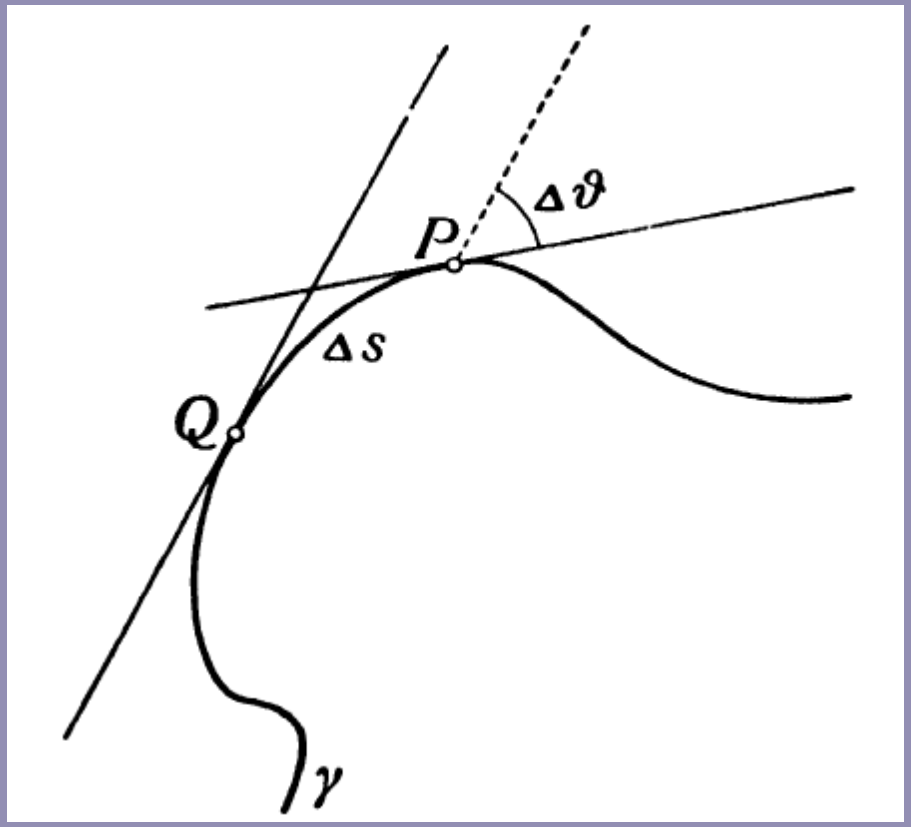
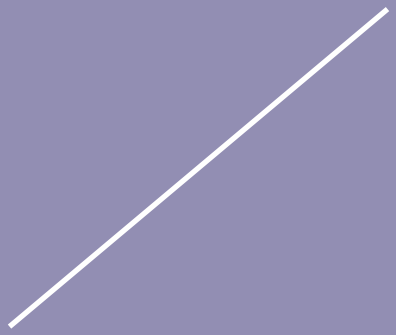


Fig. 2. *Geometric meaning of a curvature.*

The *curvature* of a curve γ at the point P is the limit of the ratio $\Delta\vartheta/\Delta s$ as the point Q approaches P.

More information can be found in [Pogorelov, 1954].

What is curvature?

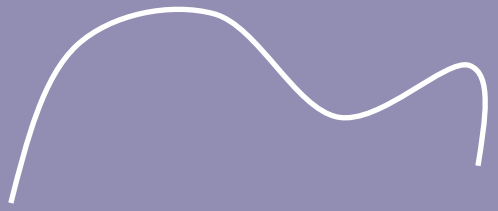


Straight line

$\kappa = 0$

Circular arc

$\kappa = const$



Bezier curve

$\kappa = \kappa(s)$

Visual Perception

- Observation of Attneave (1954) was informal but astute;
- His work helped to inspire interest in information-processing approaches to study of vision;
- Attneave's experiments were never published, but Norman et al. (2001) have conducted similar experiment and replicated Attneave's results.

Attneave's cat

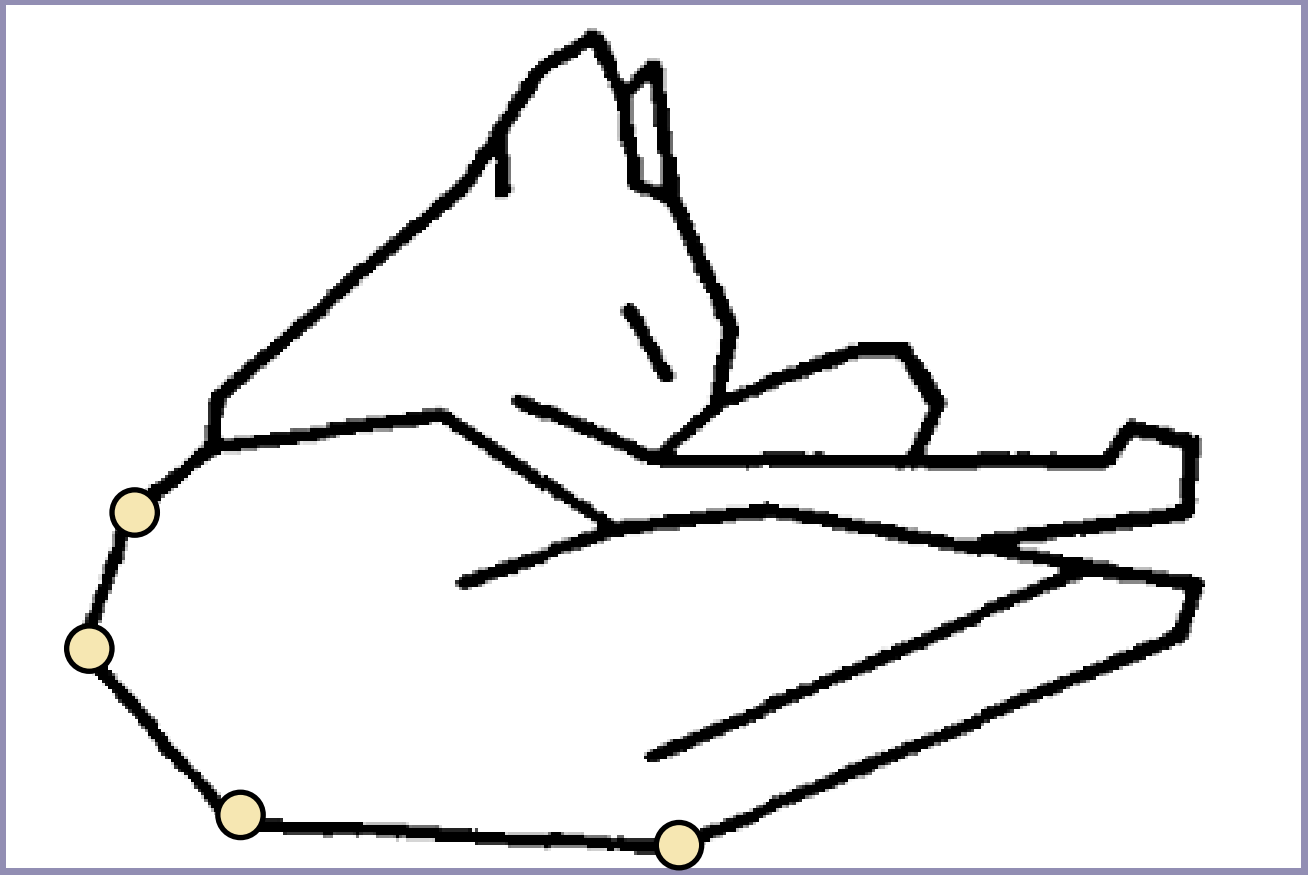


Fig. 3. *Attneave drew a line drawing of a cat by taking only the points of local maxima of curvature magnitude and joining them with straight line segment.*

Quantity of Information

- The quantity of information is sometimes called surprisal [Feldman & Singh, 2005].
- Shannon (1948) showed that the quantity of information is

$$u(M) = -\log(p(M))$$

where *p(M)* is probability density function.

Contour Information

- Feldman & Singh (2005) considered the case of simple planar curves with no self-intersections.

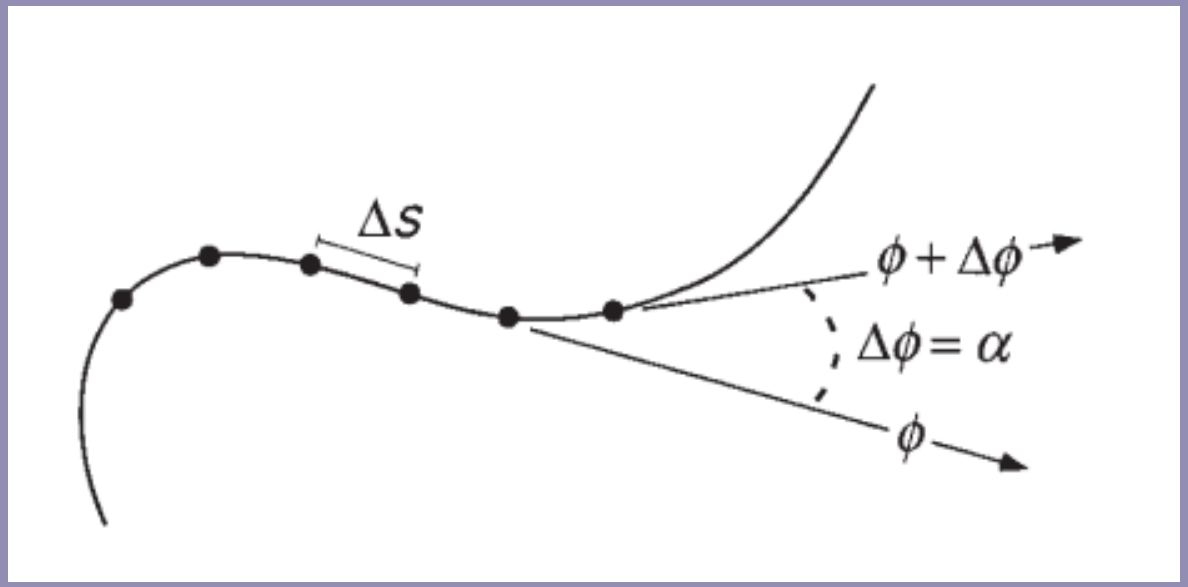


Fig. 4.

L – length, *n* uniformly spaced points separated by intervals:

$$\Delta s = L / n$$

α - turning angle.

Contour Information

• The change in tangent direction on a smooth curve follows a von Mises distribution centered on "straight" $\alpha = 0$.

$$p(\alpha) = A\exp(b\cos(\alpha))$$

- At a particular point along the curve and a particular value of turning angle α information is measured as (Feldman & Singh, 2005) :

$$u(\alpha) = -\log(p(\alpha)) = -\log A - b\cos(\alpha)$$

Contour Information

- Surprisal of a given value of curvature κ is:

$$u(\kappa) = -\log A' - b(\Delta s)^2 \cos(\kappa \Delta s),$$

and for closed contours becomes

$$u(\kappa) = -\log A' - b(\Delta s)^2 \cos(\kappa \Delta s - \frac{2\pi}{n}).$$

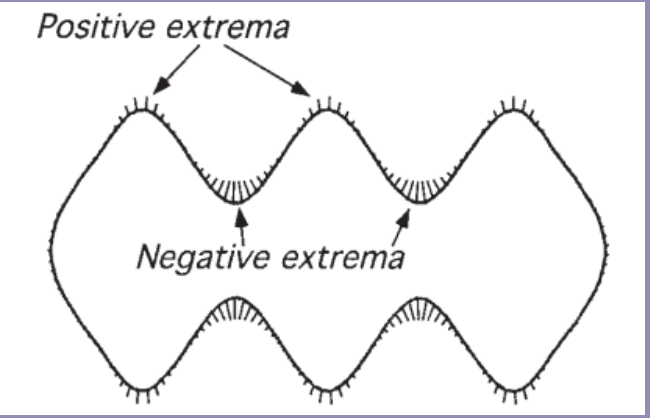
Note. The surprisal is minimal when the tangent direction turns slightly $\left(\frac{2\pi}{n}\right)$ inward.

Contour Information

Feldman & Singh (2005) conclude that:

- Information generally increases with curvature;
- Negative curvature points carry greater information than equivalent positive-curvature points (this is not depending on the precise choice of von Mises distribution);

Fig. 5. *This picture is supported by recent empirical data showing that perceptual comparisons along the contour are generally slowed by curvature and slowed even further by negative curvature, as compared with positive curvature of equal magnitude [Barenholtz & Feldman, 2003].*



Shape perception by apes

Matsuno & Tomonaga have tested negative (concavity) and positive (convexity) curvatures on the contour line.

Shape perception by apes

- A negative (concave) or positive (convex) contour apex is the point at which the curvature is locally maximal as the contour bends toward or away from the interior of the shape.
- The processing of these apexes (вершина), especially that of concavities, plays an important role in theories of object perception [e.g., Biederman, 1987; Marr & Nishihara, 1978].

Shape perception by apes

- To test the shape perception of concavity and convexity, Matsuno & Tomonaga (2007) adopted a two-alternative matching-to-sample procedure, using two-dimensional polygons;
- The chimpanzees were required to distinguish the shape of polygons from a distractor (отвлекающий) stimulus, the shape of which was deformed by adding or subtracting a concave or convex apex.

Shape perception by apes

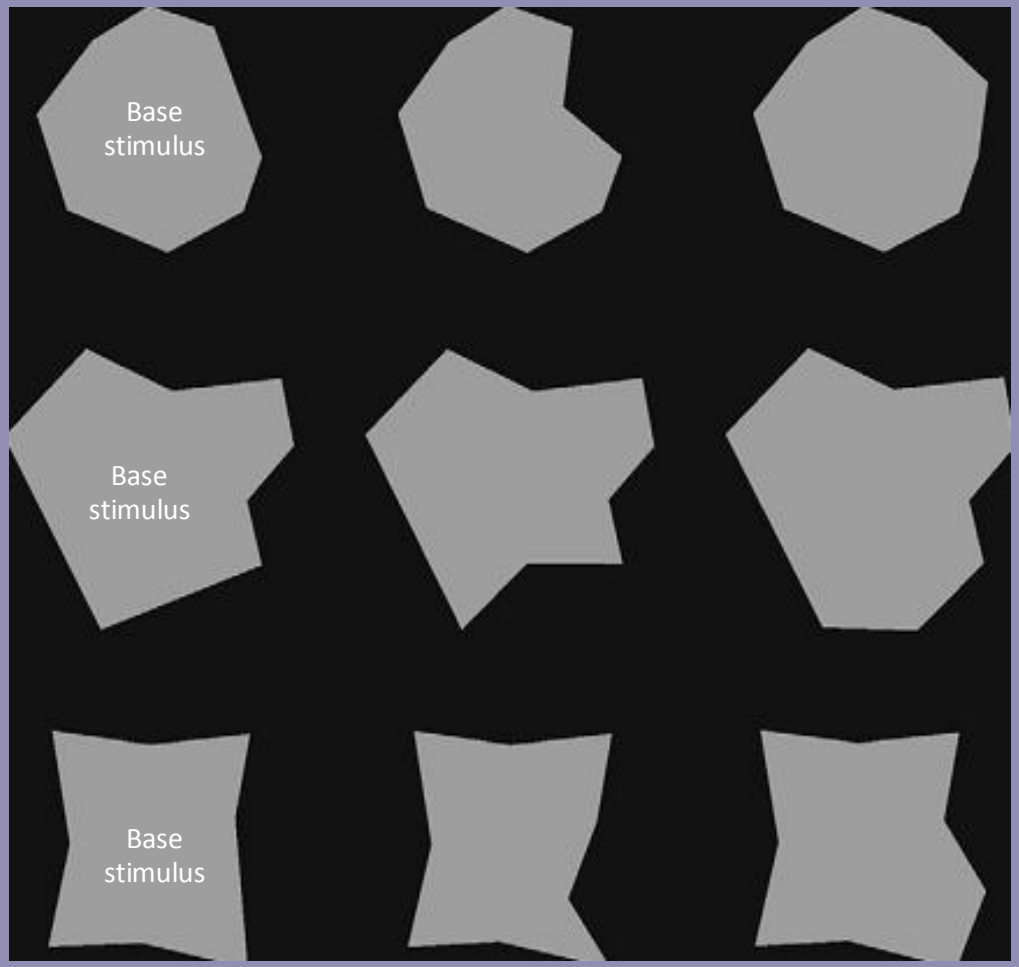


Fig. 6. *A stimulus set consisted of three polygons: one was a "base" stimulus, and the other two were deformations of the base stimulus. The base stimulus was generated by choosing 8 or 10 apexes at random locations around an arbitrarily determined centre point, using the following constraints.*

Shape perception by apes

- Chimpanzees were significantly more accurate in discerning concave than convex deformations;

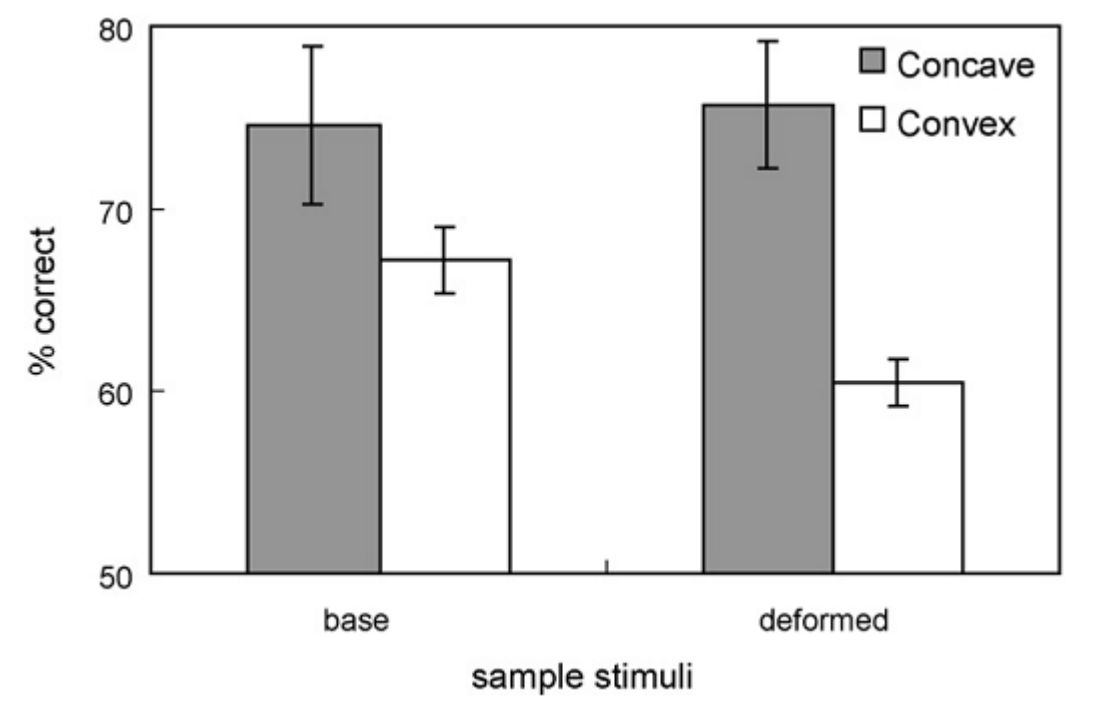


Fig. 7.

Shape perception by apes

- Results obtained by Matsuno & Tomonaga (2007) suggest that chimpanzees are more sensitive to changes in concavity than convexity;
- The perceptual tendencies of chimpanzees imply that concave cues (сигнал) are important in processing visual objects, as it presumed by human visual processing;
- Effects of concavity and convexity on the visual representation of other nonhuman animals have not been determined;

Removed slides

Slides 23-28 presenting some novel ideas were removed from this presentation.

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Thank you!
Teşekkürler!
شكرا!