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# Perceptual Foundations of Euclidean Geometry



Véronique Izard<sup>a,b,c</sup>, Pierre Pica<sup>d,e</sup> & Elizabeth S. Spelke<sup>c,f</sup>

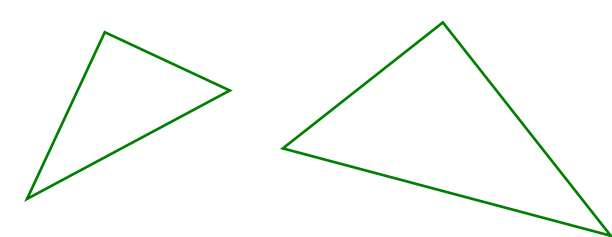
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## INTRODUCTION

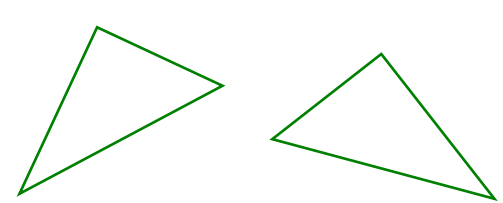
Euclidean geometry has historically be regarded as the most “natural” form of geometry (for an overview, see Hatfield, 1998). Here, we investigated whether the perception of small, 2-dimensional visual forms could provide cognitive foundations for Euclidean knowledge.

### EUCLIDEAN GEOMETRY AND ITS CLOSEST VARIANTS

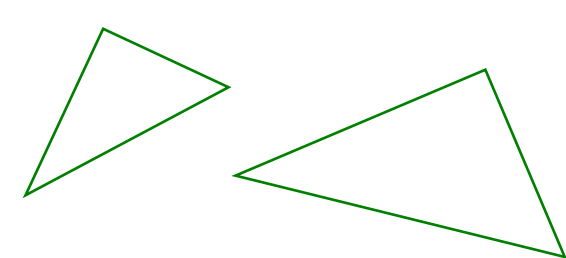
**(Euclid’s) Euclidean geometry:**  
scale- and sense-invariant (Heath, 1956)  
Relevant: metric proportions  
Irrelevant: position, orientation, sense, global size



**(modern) Euclidean geometry:**  
scaled but sense-invariant  
Relevant: metric proportions, global size  
Irrelevant: position, orientation, sense

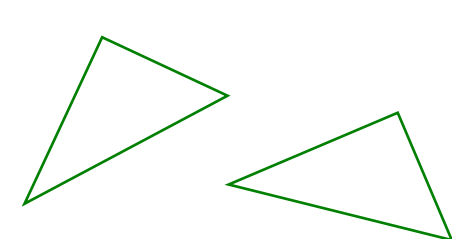


**Scale-invariant sensed geometry**  
Relevant: metric proportions, sense  
Irrelevant: position, orientation, global size



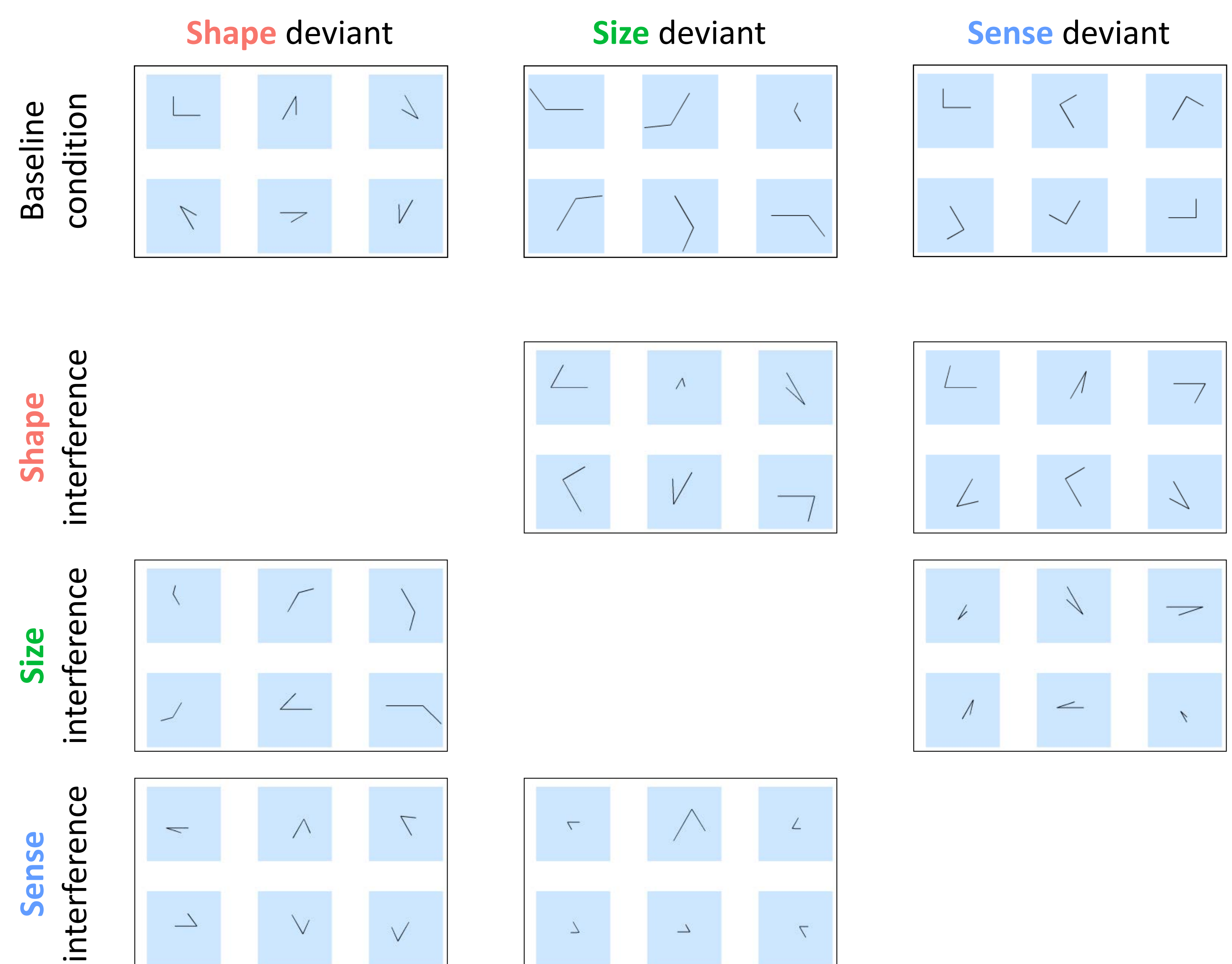
**Geometry of solid objects:**  
scaled and sensed

Relevant: metric proportions, global size, sense  
Irrelevant: position, orientation



### TASK AND DISPLAYS: « Which picture is most/very different? »

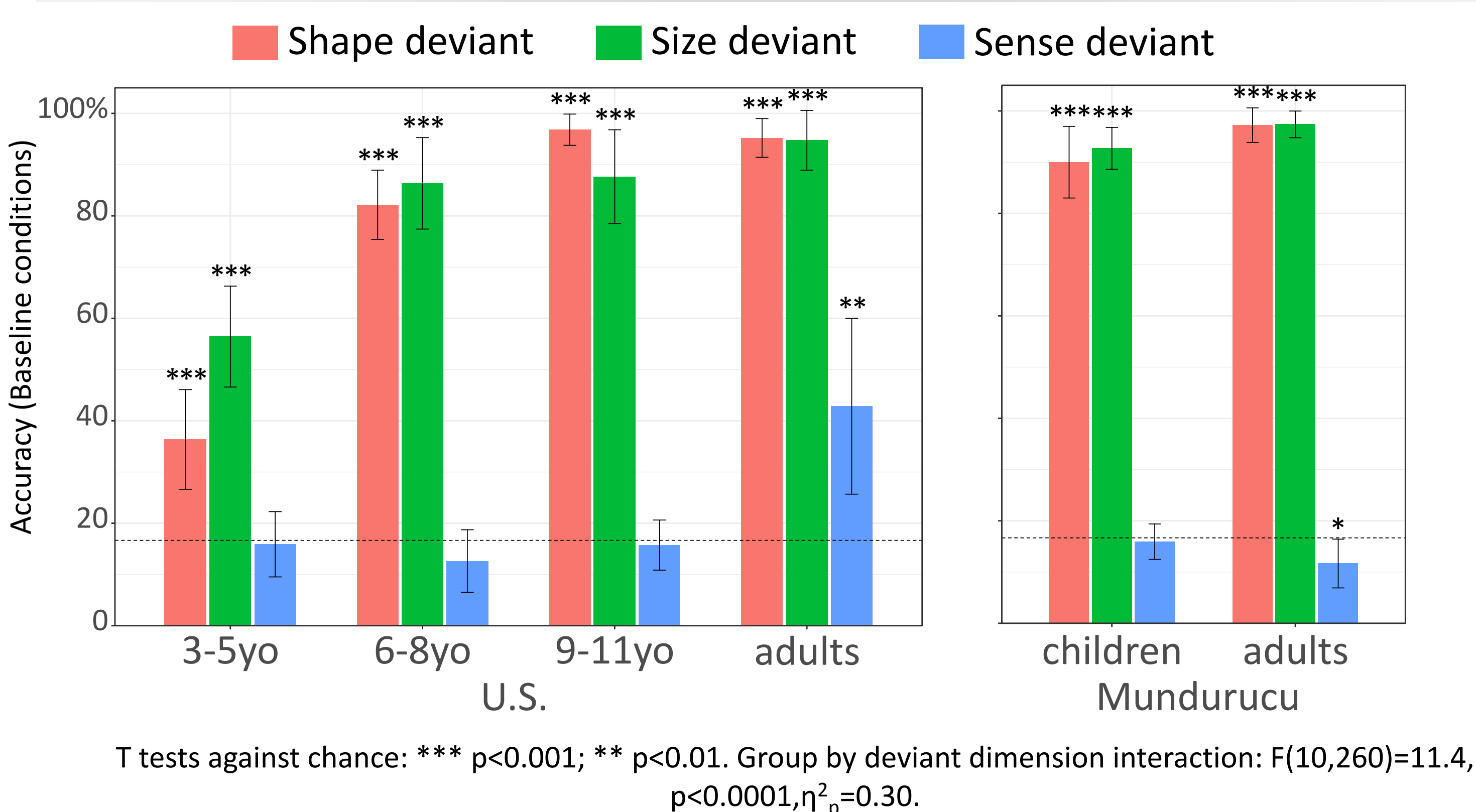
27-162 trials per participant



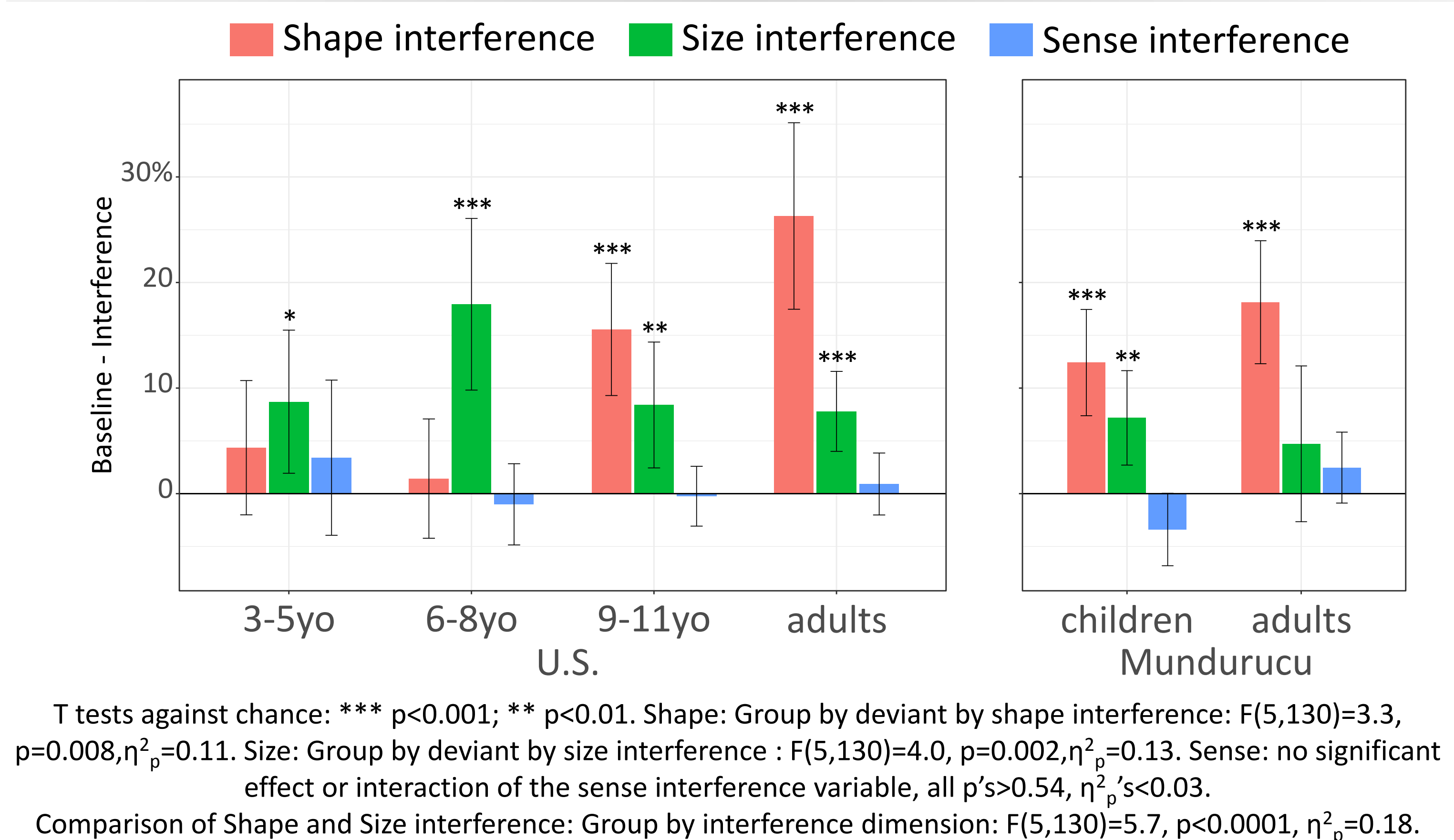
### PARTICIPANTS

U.S. 3-5yo children	U.S. 6-8yo children	U.S. 9-11yo children	U.S. Adults	Mundurucu children	Mundurucu adults
N=44	N=26	N=21	N=20	N=15	N=10
Age 3.1-5.9 y	Age 6.3-8.9 y	Age 9.4-11.8 y	Age 18-24 y	Age 5-15 y	Age 24-67 y
23 female	13 female	10 female	10 female	7 female	3 female
				14 monolingual 3 unschooled	5 monolingual 5 unschooled

### DETECTION OF SHAPE, SIZE AND SENSE DEVIANTS



### INTERFERENCE OF SHAPE, SIZE AND SENSE



## CONCLUSIONS

In all groups, participants detected shape and size deviants more easily than sense deviants. Moreover, irrelevant variations of shape and size induced interference costs, but irrelevant variations of sense had no impact on performance.

→ **(Modern) Euclidean geometry corresponds to the « natural » geometry captured by perception.**

In detail, we also found some differences across groups:

Younger children suffered greater interference of size than shape, while the reverse was true in older children and adults of both cultures.

→ During childhood, human perception evolves towards a non-scaled geometry (Euclid’s geometry).

U.S. adults chose the sense deviants, unlike every other groups.

→ Geometry-educated adults exhibit greater flexibility to switch between a sensed and a non-sensed geometry

## REFERENCES

Hatfield, G. (1998). *The Natural and the Normative: Theories of Spatial Perception from Kant to Helmholtz*. Cambridge, Massachusetts and London, England: The MIT Press.  
Heath, T. L. (1956). *The Thirteen Books of Euclid’s Elements* (2 ed.). New York: Dover Publications.

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