Violation of Leggett–Garg inequality in perceiving bistable cup-like objects

Likan Zhan [1] Andrei Khrennikov [2]

[1]Beijing Language and Culture University, zhanlikan@blcu.edu.cn [2]Linnaeus University, Andrei.Khrennikov@lnu.se

Introduction

Leggett–Garg (LG) inequality is a contextual probabilistic inequality in which one combines data collected in experiments performed for three different contexts. In the original version (Leggett & Garg, 1985) of the inequality, these contexts have a temporal nature and are given by three pairs of instances of time, $(t1, t2)$, $(t2, t3)$, $(t3, t4)$, where $t1 < t2 < t3$. It is essentially a temporal version of Bell inequality. (Asano et al., 2014) generalize the LG conditions of macroscopic realism and noninvasive measurability in the general contextual framework.

Bell-type inequalities, including the temporal ones, can be used to distinguish contextual and noncontextual realism and more generally contextual and noncontextual probabilistic representations. In this poster, we follow (Asano et al., 2014) to consider the possibility of using the generalized non-temporal LG inequality to check the "quantum-like representation" of statistical data collected in experimental studies on bistable perception of cup-like objects.

Our Experiment

Objects in Figure 1 can either be regarded as or not as a cup (a bowl, a mug, or as a vase), depending on different width-to-height ratios. To induce the bistable perception of the cup-like objects, we generated a series of 176 images of objects like Figure 1, where the width the images changes from 0.50 to 4.00 with a step of 0.02, supposing its height is fixed to 2 units. In our experiment, participants are given these objects one by one and are asked to judge whether the object is a cup or not by pressing key "Y" or "N".

Similar to (Asano et al., 2014), we manipulated three ways to present the stimuli (texting context): *decrease* (The fixed order that the width of the objects decreases from the largest to the smallest one step by one step), *increase* (The fixed order that the width of the objects increases from the smallest to the largest one step by one step), and *random* (Objects are presented in a pseudo-random order).

This experiment is a between-participant design. We recruited 31 participants in each context and 93 participants in total; obtained $5456 = 31 * 176$ judgments in each context, and $16386 = 5356 * 3$ judgments in total.

Data Analyses and Results

To analyze the data, we first code participant's "Yes" response as 1 and "No" response as -1. Second, we then clculate the mean responses of the 176 images under three testing contexts, resulting in $528 = 176 * 3$ mean values. The descriptive results are summarized in Figure 2. Third, we calculate the "K" values using the formula:

$$K(i, j, k) = C_{decrease}(i, j) + C_{increase}(j, k) - C_{random}(i, k), \text{ where } i < j < k$$

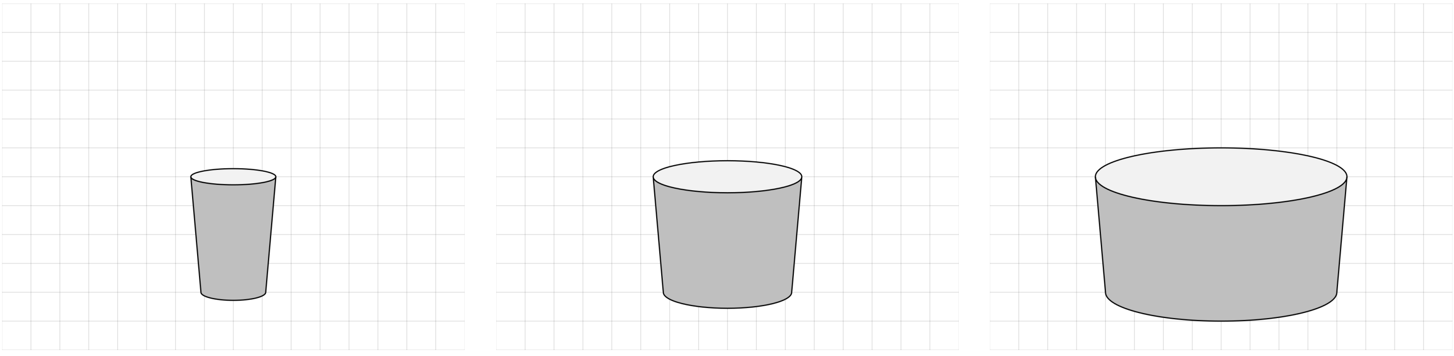
where $C_x(i, j)$ are calcuated using the formula

$$C_x(i, j) = P_x^{(i)} \times P_x^{(j)}$$

where $P_x^{(i)}$ and $P_x^{(j)}$ are the mean proportion of "Yes" response in testing context x, when the width of the object is $i, j \in \{0.50, 0.52, \cdots, 3.98, 4.00\}$.

The obtained "K" values are summarized in Figure 3. (Note: We didn't include the ones from repeated contexts). As we can see from the graph, there a substantial proportion of "K" values exceeding 1, implying the violation of Leggett-Garg inequality.

Figure 1. Cup-like Objects



(a). Width = 1 (b). Width = 2 (c). Width = 4

Selected References

Asano, M., Hashimoto, T., Khrennikov, A., Ohya, M., & Tanaka, Y. (2014).**Violation of contextual generalization of the leggett–garg inequality for recognition of ambiguous figures.** **Physica Scripta**, **T163**. **https://doi.org/10.1088/0031-8949/2014/t163/014006**

Leggett, A. J., & Garg, A. (1985).**Quantum mechanics versus macroscopic realism: Is the flux there when nobody looks?** **Physical Review Letters**, **54(9)**, **857–860. https://doi.org/10.1103/PhysRevLett.54.857**

Figure 2. Descriptive Analyses

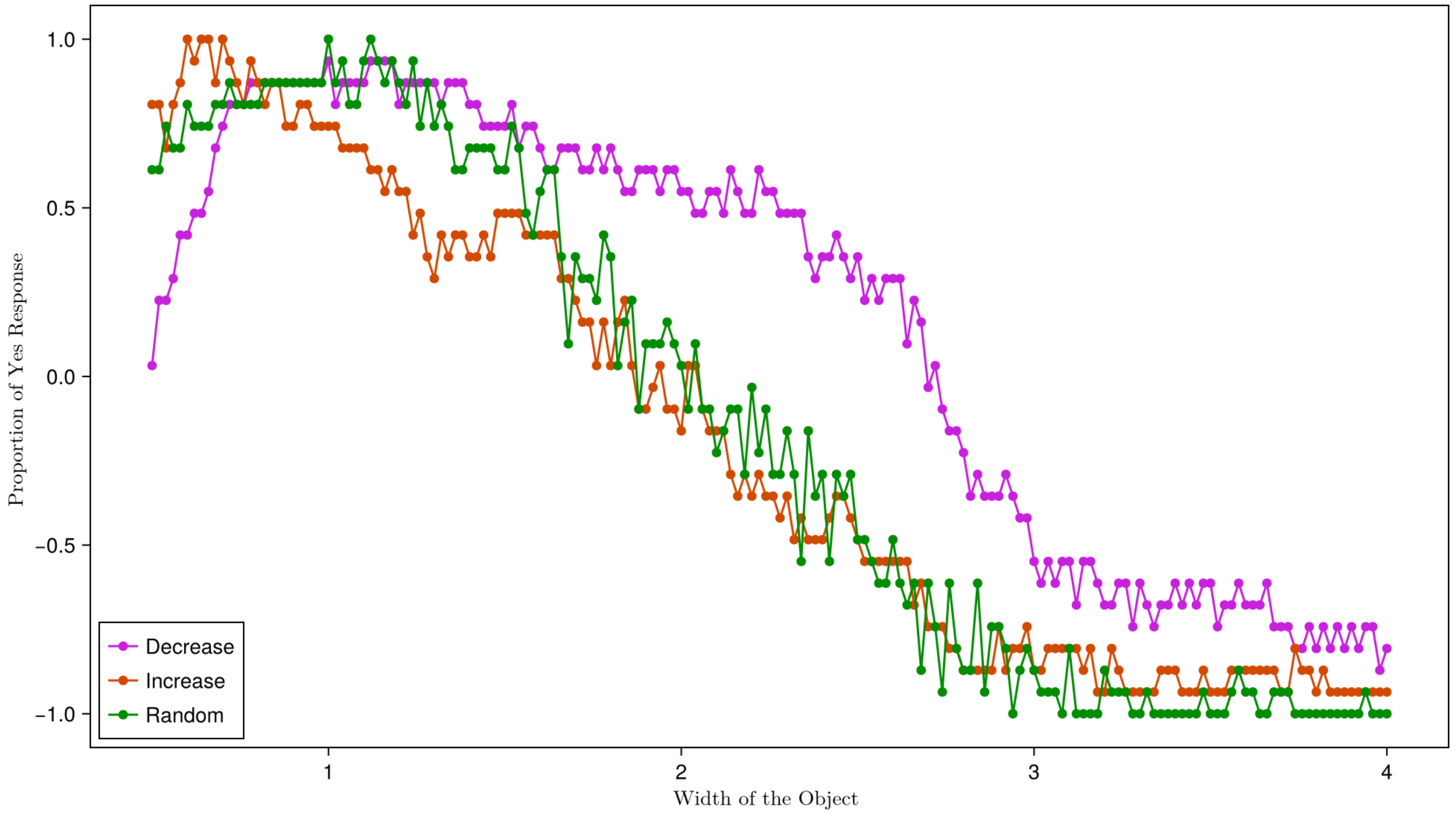
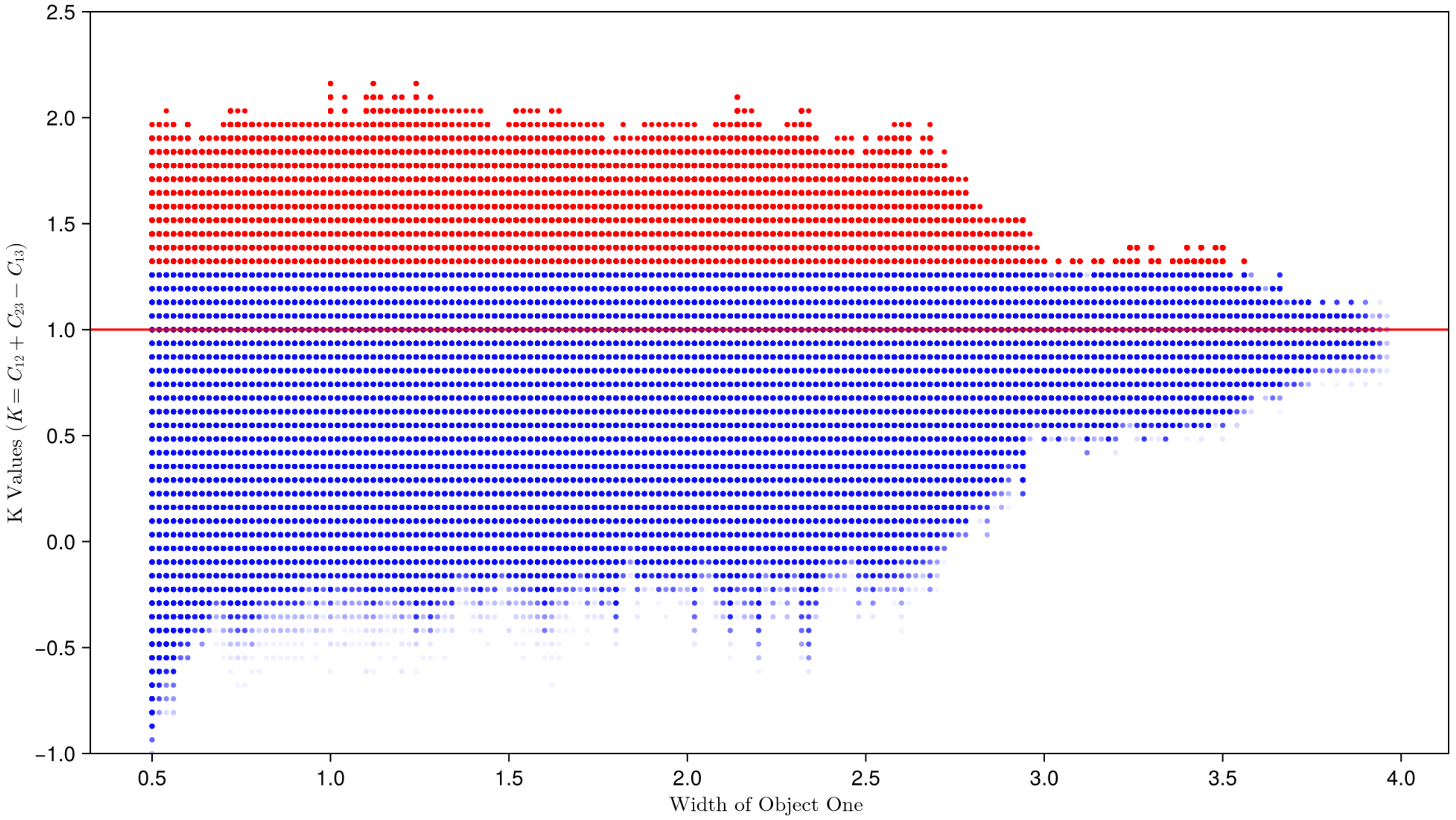


Figure 3. Violation of Leggett–Garg Inequality



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