

Non-symbolic numerical distance effect

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Experiment software: PsychoPy

Estimated running time: 5 minutes

Theoretical background

When two array of items are compared approximately, the error rate increases if the numerical difference between the two arrays decreases. This phenomenon is called the numerical distance effect. Critically, the error rate is predicted by the ratio of the two values. The ratio is important here: it is a well-known signature of a noisy and continuous representation working according to Weber's law. According to Weber's law two stimuli can be discriminated if the ratio of them is above a specific threshold value. This value can be specified for any continuous perceptual property. Thus, numerosity of an array is stored in a noisy and continuous representation.

The present demonstration shows that it is the ratio of the arrays, and not the difference of the arrays that determine the error rate in an approximate array comparison task.

Procedure

In a trial the participant has to choose the larger of two arrays on the two sides of the screen.

In many dot comparison task the size of the items, the density of the items, the full luminance of an array, etc. are controlled. This control could ensure that the comparison is based on the numerical features of the set and not on the perceptual features of it. The control should be quite tricky, because we have less degree of freedom than the variables we want to control. It means that, for example, if you want to control the density of the items, and the number of the items is given, then you cannot control the whole area the array covers, because it is already determined by the number and the density. Still, there are many procedures how to control at least some of the parameters. See a list of references and a technical description of the control in Dehaene, Izard and Piazza (2005).

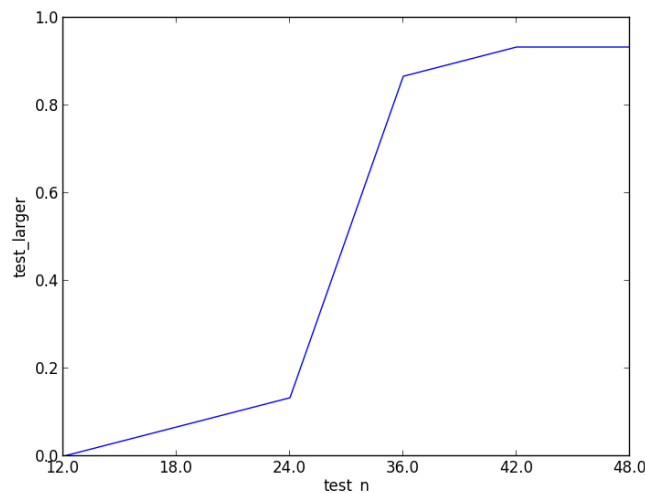
However, in the present demonstration a more simple stimulus is used in which small black and white items are applied (e.g., Burr & Ross, 2008; Dakin et al., 2011).

In the experiment one of the array is always a fixed value (reference number). The other array (test number) varies with specified ratios: -60%, -40%, -20%, +20%, +40% and +60%. When starting the demonstration one can choose whether the reference number should be 15 or 30. The test arrays will be generated according to the percentage values and the reference number,

e.g., the -20% pair of the 15 reference value is $15 - 20\% \times 15$, which is 12.

Expected results

At the end of the demonstration, the ratio of the test number choice as the function of the test array will be displayed (see an example figure below). It means that if the test value is smaller than the reference number (i.e., -60%, -40% and -20%), usually the reference is chosen, thus, the ratio will be low. However, if the test value is larger than the reference value (i.e., +20%, +40% and +60%), usually the test will be chosen, thus, the ratio will be high. This is the typical display form of psychophysical curves, and one should see a S shaped curve. Still, this graph could be converted to an error rate graph. When the ratio of test number choice is close to 0% on the left side or 100% on the right side, the error rate is low. Conversely, 100% on the left side and 0% on the right side means maximum error rate. When the ratio of the responses is around 50%, the choice is random.



Additionally, if the distance between the test and the reference value is small (e.g., -20% or +20%, the ratio will be closer to the 50%, because it is hard to decide which array is the larger when the difference is small. On the other hand, the ratios will be close to 0% or 100% when the ratio of the test and reference values is high (e.g., -60% or +60%). This is the distance effect.

Critically, running the demonstration with both the 15 and the 30 reference values, one should typically find the similar response ratios curve in the two versions, because the data are displayed as the ratio of the test and the reference arrays, which determines the ratio of the responses. This shows that the distance effect depends of the ratios of the arrays.

References

Burr, D., & Ross, J. (2008). A Visual Sense of Number. *Current Biology*, 18(6), 425–428.
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Dakin, S. C., Tibber, M. S., Greenwood, J. A., Kingdom, F. A. A., & Morgan, M. J. (2011). A common visual metric for approximate number and density. *Proceedings of the National Academy of Sciences*, 108(49), 19552–19557. doi:10.1073/pnas.1113195108

Dehaene, S., Izard, V., & Piazza, M. (2005). Control over non-numerical parameters in numerosity experiments. Retrieved from <http://www.unicog.org/pm/pmwiki.php/Main/Arithmetics>

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