BACKGROUND

The comparison of two stimuli is often affected by their presentation order. The nature – perception or response bias – of the time-order and space-order effects (TOEs, SOEs) – is long-debated. Here we analyze timed comparisons to address a related topic: the nature of the 'initial bias' in the random-walk account of stimulus comparison.

In Random Walk Theory, evidence accumulation (Fig. 1) starts at c (Initial bias) and ends at a barrier: A (response '1st/3rd greater', probability = P), or –A (response '2nd/4th greater', probability = 1 - P).

\[
\mu = \text{drift rate (accumulation speed), proportional to the mean subjective interstimulus difference}.^2 \text{ Assuming } \mu \text{ to be normally distributed}, N(\mu, \sigma^2), \logit P = \ln \left( \frac{P}{1-P} \right) = 2 \mu \sigma^2. \text{ For a single trial, with } c = 0, \mu / A \text{ can also be estimated by Signed Response Speed, } SRS = \pm 1 / RT, \text{ with } +/- \text{ sign for } "1st/2nd \text{ greater}". \text{ For each stimulus pair, over replications, } M_{SRS} \text{ estimates } \mu / A.
\]

THE EXPERIMENTS

Paired light spots – successive, with varying ISIs (Exps. 1-2) or simultaneous, with varying spatial separations (Exps. 3-4) – were compared. The brighter (Exps. 1, 3), or larger (Exps. 2, 4) spot was chosen, and responses were timed. The subjective stimulus difference \( \mu \) in each pair was scaled, using (i) \( \logit P = \ln \left( \frac{P}{1-P} \right) \) and (ii) Signed response speed (SRS) = 1/RT.

Chromometric (CM) analysis.

With \( c = 0 \) and \( E(SRS) = 0 \), \( P/(1-P) = (A-c)/(A+c) \) and thus \( \logit P = \ln[(1-q)/(1+q)] \), where \( q = c/A \). Thus the intercept in the plot of \( \logit P \) vs. \( M_{SRS} \) (Fig. 2) estimates relative bias, \( q \). (This estimate is independent of nondecision time, \( \tau \), whose influence on SRS vanishes when 1/RT \( \rightarrow 0 \).)

Diffusion model (DM) analysis. The Ratcliff Diffusion Model was fitted to the timed responses with the program WinBUGS, yielding a \( q \) estimate for each ISI/separation and an \( A \) estimate for each participant. The \( q \) estimates are highly correlated with those from CM analysis, but, for unclear reasons, about three times larger.

Fig. 1. Random-walk response process in stimulus comparison with initial bias.

Fig. 2. Sample plots of \( \logit P \) vs. \( M_{SRS} \).

Hellström's Sensation Weighting (SW) Model accounts for TOEs/SOEs. Each sensation magnitude, \( \psi_i \), is \( s \)-weighted together with a reference level (RL), \( \psi^* \).

\[
d = [k s_1 (\psi_1 - \psi^*)] - [k s_2 (\psi_2 - \psi^*)] + b, \quad \text{where } d = \text{perceived stimulus difference and } b \text{ possible bias}. k \text{ is a scale constant. For a pair of equal stimuli, } d \text{ is often } 0, \text{ indexing TOE or SOE. A simplified version is } d = W_1 \psi_1 - W_2 \psi_2 + U, \text{ where } W_1 = k s_1 \text{ and } W_2 = k s_2. \text{ When } \psi_1 \text{ and } \psi_2 \text{ are at their means, } U \text{ indexes the TOE or SOE.}
\]

conditioning and TOE/SOE. For each ISI or separation, the correlation (over participants) between TOE/SOE and \( q \) was found to be positive. Thus, initial bias contributes to TOE/SOE. But how?

Two hypotheses on nature of initial bias \( q \).

(i) Response preference: \( q \) reflects bias term \( b \). (ii) Evidence accumulation is Rel-primed, starting with null assumptions \( \psi_1 = \psi^* \) and \( \psi_2 = \psi^* \), so that \( q \) reflects \( \psi_1 - \psi_2 \).

Component structure of initial bias. For each experiment, a principal component analysis of all eight \( q \) estimates from CM and DM analyses yielded two orthogonal components (C1, C2). Similarly for all experiments (Fig. 3 shows Exp. 2), \( q \) loads positively in C1 for all ISIs/separations; in C2, \( q \) loads negatively for small, and positively for large ISIs/separations.

Response assignment. In Exps. 1 and 2, half of the participants used the left (right) hand to indicate "1st (2nd) spot brighter/larger" (RA1) and half did the reverse (RA2). The criterion \( A \) was higher for those using RA2, \( p = .027 \) (Exp. 1) and \( p = .001 \) (Exp. 2). This suggests that the less ‘natural’ assignment, RA2, required more accumulated evidence for responding. In Exp. 1, \( M_{C1} \) was negative for RA1 but positive for RA2, \( p = .012 \), suggesting a general preference for using the right key.

CONCLUSION

- Although the initial relative bias, \( q \), is not the main factor behind the TOE/SOE, it contributes to it.

- In some experiments, \( q \), as well as response criterion \( A \), may be sensitive to the response assignment, partially supporting hypothesis (i).

- Yet, \( q \) also has a component that depends, in a participant-specific manner, on the temporal ( ISI) or spatial stimulus separation.

REFERENCES