Assessment and Interpretation of Bias in 2AFC Stimulus Comparison Through Chronometric Analysis

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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[2] evidence accumulation (Fig. 1) starts at *c* (Initial bias) and ends at a barrier: *A* (response '1st/left greater', probability = *P*), or –*A* (response '2nd/right greater', probability = 1-*P*).

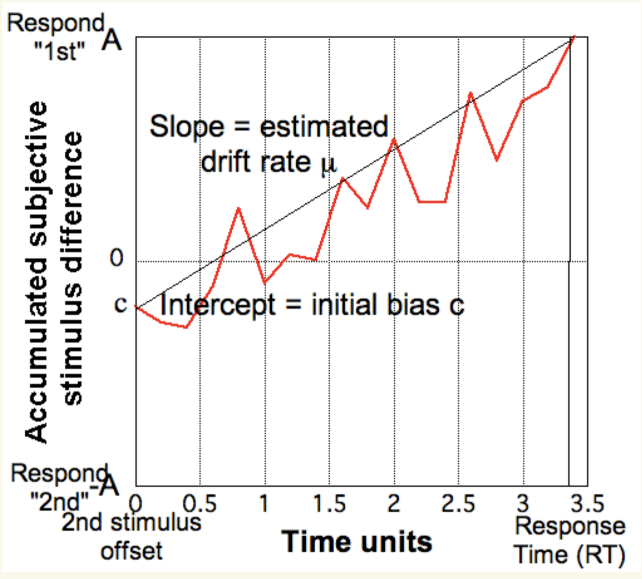

Fig. 1. Random-walk response process in stimulus comparison with initial bias.

μ = drift rate (accumulation speed), proportional *to* the mean subjective interstimulus difference[2]. Assuming μ to be normally distributed[4], $N(\mu,\sigma^2)$, logit $P = \ln[P/(1-P)] = 2\mu A/\sigma^2$. For a single trial, with $c = 0$, μ/A can also be estimated by Signed Response Speed, $SRS = \pm 1/RT$, with +/- sign for "1st/2nd greater". *RT* = response time. For each stimulus pair, over replications, M_{SRS} also estimates μ/A.

THE EXPERIMENTS[3]

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 μ in each pair was scaled, using (i) logit $P = \ln[P/(1-P)]$ and (ii) Signed response speed (SRS) = $1/RT$.

Chronometric (CM) analysis.
With $c \neq 0$ 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, τ, whose influence on *SRS* vanishes when $1/RT \to 0$.)

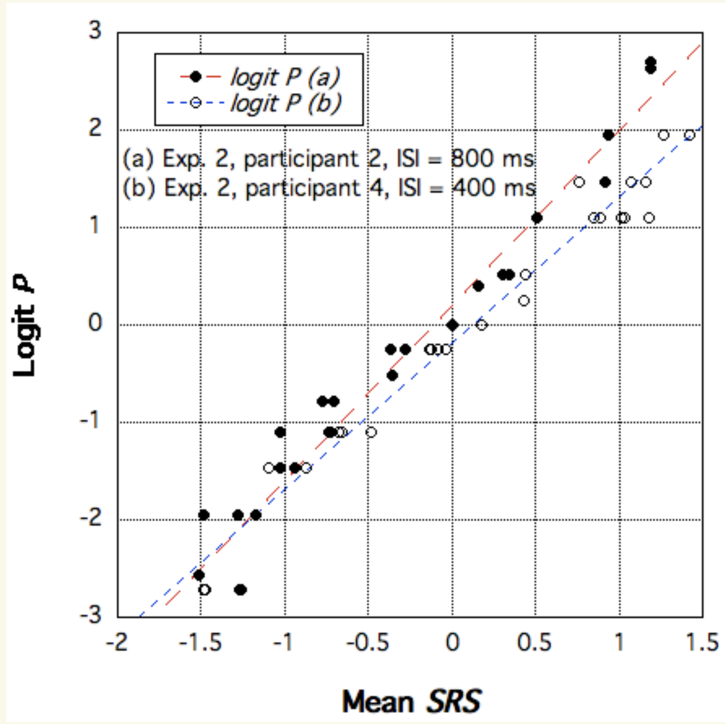

Fig. 2. Sample plots of logit *P* vs. M_{SRS}.

Diffusion model (DM) analysis. *The* Ratcliff Diffusion Model[3] 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.

Hellström's Sensation Weighting (SW) Model[1] accounts for TOEs/SOEs. Each sensation magnitude, ψ, is *s*-weighted together with a reference level (ReL), ψ_r:
$d = [ks_1(\psi_1-\psi_{r1}) - ks_2(\psi_2-\psi_{r2}) + (\psi_{r1}-\psi_{r2})] + b$,
where d = perceived stimulus difference and *b* possible bias. *k* is a scale constant. For a pair of equal stimuli, *d* is often ≠ 0, indexing *TOE* or *SOE.* A simplified version is
$d = W_1\psi_1 - W_2\psi_2 + U$,
where $W_1 = k\,s_1$ and $W_2 = k\,s_2$. When ψ_1 *and* ψ_2 are at their means, *U* indexes the TOE or SOE.

initial bias 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 $\psi_1 = \psi_{r1}$ and $\psi_2 = \psi_{r2}$, so that *q* reflects $\psi_{r1} - \psi_{r2}$.

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.

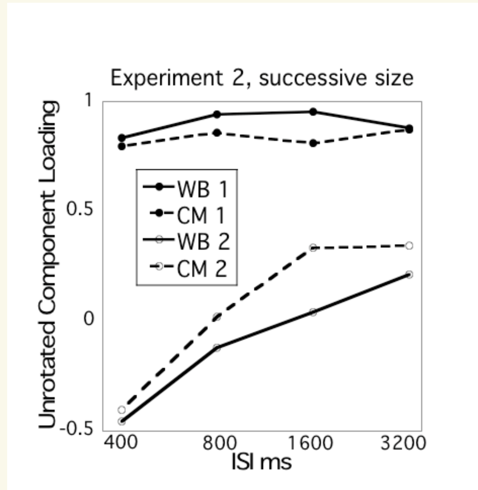

Fig. 3a. Exp. 2: Unrotated loadings of *q* ests. in comps. *C1*, *C2* (eigenvalues 6.15, 0.68) vs. ISI.

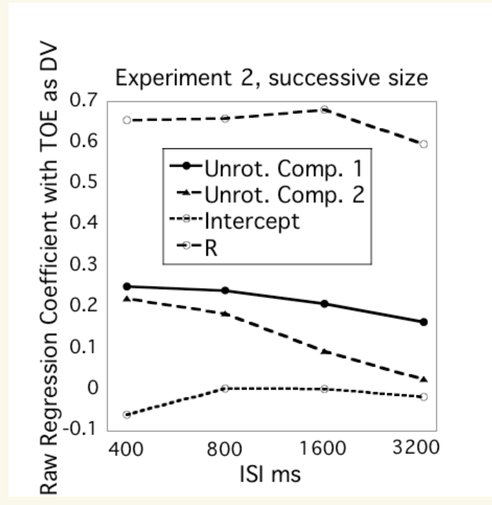

Fig. 3b. Exp. 2: Regression coefficients of *C1* and *C2* in determining TOE, vs. ISI.

The impact of *C1* and *C2* on TOE and SOE was studied by linear regression of *U* on the unrotated component scores. About half of the variance of *U* is due to *C1* and *C2*. When contributing to the TOE/SOE (by the coefficients in Fig. 3b), *C1* and *C2* are weighted-in in a different pattern than that shown by their *q* loadings in Fig. 3a.

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.

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(4) Shadlen, M. N., et al. (2007). In K. Doya et al. (Eds.), *Bayesian brain* (pp. 209-237).

Fechner Day 2011, October 24–27, Herzliya, Israel