Supporting information for Vorberg *et al.* (2003) *Proc. Natl. Acad. Sci. USA*, 10.1073/pnas.0931489100

Supporting Text

A. What Can Be Inferred from Double Dissociations?

Let ***C*** and ***U*** denote sensory information that is potentially accessible to conscious awareness or remains unconscious, respectively, and let c and u denote their strengths. We assume that c and u are arbitrary functions of the experimental conditions; for simplicity, and we assume $c, u \geq 0$. Consider empirical measures R and P that seek to assess the amount of each type of sensory information available to the subject. Nothing is assumed about their scales except that larger values reflect larger effects on both. Ideally, the direct measure R (for recognition) and the indirect measure P (for priming) index either conscious or unconscious information exclusively, respectively, but because they might be contaminated by the other type as well, we model them as functions of two arguments.

Assumption. $R = R(c,u)$ and $P = P(c,u)$ are weakly monotonic in either argument, i.e., $R(c,u) \leq R(c',u')$ and $P(c,u) \leq P(c',u')$ for all $c \leq c'$ and $u \leq u'$.

Weak monotonicity allows interactive effects on each measure, but interactions must be ordinal, e.g., $R(c,u) \geq max[R(c,0), R(0,u)]$.

Proposition. Let R_k and P_k denote the effects of some experimental conditions, $k = 1, 2$, on recognition and priming, respectively. Observing different effect orders $R_1 > R_2$ and $P_1 < P_2$ for recognition and priming is incompatible with the assumption that the amount of only one type of information varies across conditions.

Proof. We prove that $u_1 \neq u_2$ by showing that the assumption $u_1 = u_2 = u$ leads to a contradiction:

(*i*) $R_1 > R_2 \Rightarrow R(c_1,u) > R(c_2,u) \Rightarrow c_1 > c_2$

(*ii*) $P_1 < P_2 \Rightarrow P(c_1,u) < P(c_2,u) \Rightarrow c_1 < c_2$.

By the same argument, $c_1 = c_2$ can be excluded. Different effect orders thus imply either ($c_1 > c_2$ and $u_1 < u_2$) or ($c_1 < c_2$ and $u_1 > u_2$), which shows that the amount of the two types of information must have been affected in opposite ways by the experimental manipulation.

Example. Consider the 42-ms primes followed by 42-ms masks in Experiment 2. Within the stimulus-onset asynchrony (SOA) range from 42 to 98 ms, recognition accuracy declines with SOA, whereas the net amount of priming increases. Letting $u = u(\text{SOA})$ and $c = c(\text{SOA})$, these findings imply either $\{c(42) > c(98)$ and $u(42) < u(98)\}$ or $\{c(42) < c(98)$ and $u(42) > u(98)\}$. However, they rule out $c(42) = c(98)$ as well as $u(42) = u(98)$ and therefore reject the assumption that only one type of information changes with SOA. Thus, without specifying how the amount of sensory information depends on SOA, we can conclude that the observed double dissociation cannot be accounted for by the assumption that the indices tap at one and the same information, whatever their sensitivity. At least two types of internal signal have to be assumed.

Remark. To keep matters simple, we have ignored statistical issues, but the arguments remain valid if R_i and P_j are thought of as expected values, as long as c and u are constants. Replacing c and u by random variables $\mathbf{C}$ and $\mathbf{U}$**,** with distributions that depend on experimental conditions, the proposition above still holds if the premises $R_1 > R_2$ and $P_1 < P_2$ are replaced by the stochastic conditions

(i) $Pr_1\{R(\mathbf{C},\mathbf{U}) \le t\} \le Pr_2\{R(\mathbf{C},\mathbf{U}) \le t\}$ and $Pr_1\{P(\mathbf{C},\mathbf{U}) \le t\} \ge Pr_2\{P(\mathbf{C},\mathbf{U}) \le t\}$ for all t,

(ii) $Pr_1\{R(\mathbf{C},\mathbf{U}) \le t\} < Pr_2\{R(\mathbf{C},\mathbf{U}) \le t\}$ and $Pr_1\{P(\mathbf{C},\mathbf{U}) \le t\} > Pr_2\{P(\mathbf{C},\mathbf{U}) \le t\}$ for some t.

B. Analysis of the Priming Function

By the assumptions stated in the text, each of the two accumulators describes a stochastic immigration-death process. For an immigration-death process with input parameter λ_i starting at time $t = 0$ from an initial number of effects n_0, the total number of accumulated and nondecayed effects by time t is Poisson-distributed with mean

$$n(t) = \frac{\lambda_i}{\nu}\left(1 - e^{-\nu t}\right) + n_0 e^{-\nu t}$$

(1). This is easily generalized into a form that can be applied to arbitrary intervals [s, t], inside which the input parameters are constant:

$$n(t) = \frac{\lambda_i}{\nu}\left(1 - e^{-\nu(t-s)}\right) + n(s) e^{-\nu(t-s)}.$$

When t increases, the mean approaches λ_i/ν, with rate ν.

To gain insight into the model, we approximate each stochastic process by its mean $n(t)$. We assume that a prime remains effective until the mask follows at $SOA = s \ge 0$. A response is initiated as soon as the difference between the accumulator states, $d(t)$, reaches the threshold c. A left response is elicited if $d(t) \ge c$, a right one if $d(t) \le -c$.

Case 1: Prime Congruent. For concreteness, consider trials requiring a left response. Because primes and masks are equally effective, the input parameter of the left-response accumulator equals $\lambda + \lambda_b$ both from prime to mask onset at SOA = *s* and thereafter, whereas the right-response accumulator has input λ_b throughout. The mean accumulator states at time *t* are thus given by

$$n_L(t) = \frac{\lambda + \lambda_b}{\nu}\left(1 - e^{-\nu t}\right) + n_L(0)e^{-\nu t},$$
$$n_R(t) = \frac{\lambda_b}{\nu}\left(1 - e^{-\nu t}\right) + n_R(0)e^{-\nu t},$$

such that the difference $d(t) = n_L(t) - n_R(t)$ equals

$$d_{cong}(t) = \frac{\lambda}{\nu}\left(1 - e^{-\nu t}\right),\ t \geq s\ ,$$

if the accumulator means are equal initially, i.e. $n_L(0) = n_R(0)$.

We approximate the mean reaction time on congruent trials, RT_{cong}, by the time at which the mean difference reaches the threshold *c*, i.e., we solve $d_{cong}(t^*) = c$. A solution exists if $c < \lambda / \nu$; it is given by

$$RT_{cong} \cong t^* = \frac{1}{\nu}\ln\frac{\lambda}{\lambda - c\nu}.$$

By symmetry, the derivation for congruent trials requiring right-hand responses gives the same result.

Case 2: Prime Incongruent. On left-response trials, the incongruent prime feeds the right-hand accumulator with $\lambda + \lambda_b$ until the mask is presented at time *s*, and with λ_b thereafter. Thus, for $t < s$,

$$n_R(t) = \frac{\lambda + \lambda_b}{\nu}\left(1 - e^{-\nu t}\right) + n_R(0)e^{-\nu t},$$

and for $s \leq t$,

$$\begin{aligned} n_R(t) &= \frac{\lambda_b}{\nu}\left(1 - e^{-\nu(t-s)}\right) + n_R(s)e^{-\nu(t-s)} \\ &= \frac{\lambda_b}{\nu}\left(1 - e^{-\nu(t-s)}\right) + [\frac{\lambda + \lambda_b}{\nu}\left(1 - e^{-\nu s}\right) + n_R(0)e^{-\nu s}]e^{-\nu(t-s)}. \end{aligned}$$

In contrast, the input rate for the left-hand accumulator is λ_b for 0 $t < s$ and switches to $\lambda + \lambda_b$ when the mask is presented. Thus, for $t < s$,

$$n_L(t) = \frac{\lambda_b}{\nu}\left(1 - e^{-\nu t}\right) + n_L(0)e^{-\nu t},$$

and for $s \leq t$,

$$\begin{aligned} n_L(t) &= \frac{\lambda + \lambda_b}{\nu}\left(1 - e^{-\nu(t-s)}\right) + n_L(s)e^{-\nu(t-s)} \\ &= \frac{\lambda + \lambda_b}{\nu}\left(1 - e^{-\nu(t-s)}\right) + [\frac{\lambda_b}{\nu}\left(1 - e^{-\nu s}\right) + n_L(0)e^{-\nu s}]e^{-\nu(t-s)}. \end{aligned}$$

Inserting and simplifying, the expected accumulator difference $n_L(t) - n_R(t)$ on incongruent trials is found as

$$d_{incong}(t) = \frac{\lambda}{\nu}\left[1 - e^{-\nu t}\left(2e^{\nu s} - 1\right)\right].$$

As before, we solve for time t^* when the difference reaches the threshold c, which approximates the mean RT on incongruent trials:

$$RT_{incong} \cong t^* = \frac{1}{\nu}\ln\lambda\frac{2e^{\nu s} - 1}{\lambda - c\nu}.$$

Note that no solution exists (i.e., RT_{incong} is infinite) unless $c < \lambda / \nu$.

Combining these results yields the priming function, i.e., the net priming effect as a function of the prime-target SOA given in the text.

Reference:

1. Cox, D. R. & Miller, H. D. (1965) in *The Theory of Stochastic Processes* (Chapman & Hall, London), p. 169.