CHARACTERIZING ATTENTION IN TERMS OF CHA

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BACKGROUND

In standard Signal Detection Theory, decisions on two (or more) independent events explicitly tagged are taken independently. The decisional behavior assessed for each of the two events separately, should be the same as the one assessed when the two events are mixed together (dual task). Gorea & Sagi (2000, 2001, 2002a,b, 2004, 2005) have shown otherwise: when the two events are tested together subjects tend to report the less salient (lower d') events less, and the more salient ones more than when they are tested independently. Sjs appear to use a *unique criterion* for their decisions taken on two unequally salient events, a clear departure from optimality. Gorea & Sagi accounted for this behavior in terms of a model where the internal representations evoked by each of the two events are merged and a unique criterion is set with respect to this *unified internal representation* (**Figure 1**). However, not all the 10 experiments run over years with different visual-visual (VV), audio-audio (AA) and audio-visual (AV stimulus pairs; **Figure 2**) yielded the unique criterion behavior (**Figure 3**).

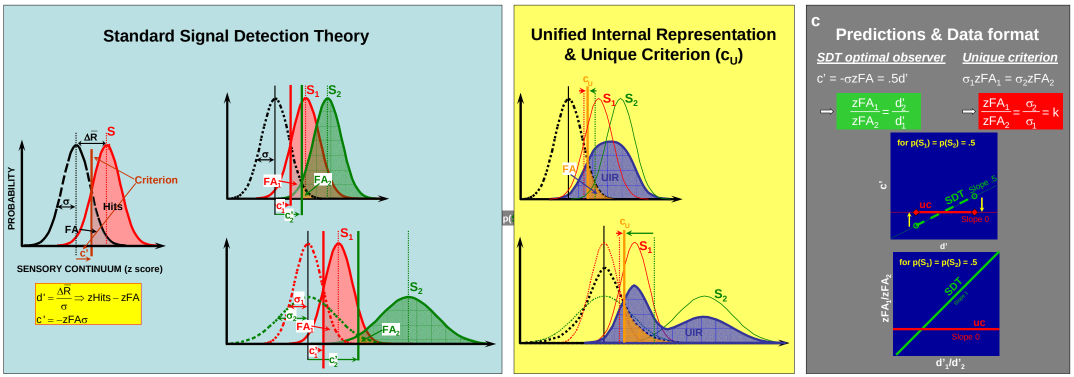

Figure 1. **(a)** Standard Signal Detection Theory framework for detection of one (left) and two unequally salient events yielding equal (top) or unequal internal noises. **(b)** The equivalent representation for the detection of two events under the *unique internal representation (uir)* for equal (top) and unequal related internal noises. **(c)** Predicted criteria and criteria ratio as a function of d' and d' ratio under SDT and *uir*, respectively.

METHODS

All experiments were of the Yes/No type run under two formats: **(1)** ***Single (S)* format.** Throughout an experimental block Sjs attended and responded to only one of the two presented stimuli; **(2)** ***Dual (D)* format.** Sjs had to attend to both stimuli and were randomly asked to decide on the occurrence of one of them (*partial report*).

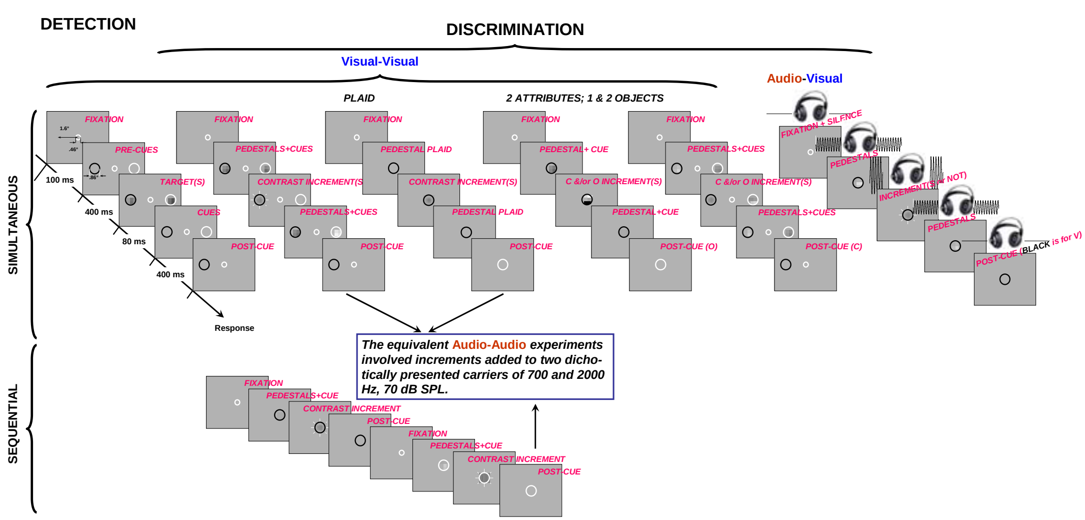

Figure 2. Different experimental formats used for Single and Dual detection and discrimination tasks with paired Visual-Visual, Audio-Audio and Audio-Visual stimulations presented either simultaneously or in sequence.

PURPOSE & DATA

Why do some experimental conditions display the *unique criterion* (*uc*) behavior while others do not?

Note that the occasional failure of *uc* in Fig. 3 is in fact a *failure of zFA equality*. This a failure reflects a *uc* (i.e. σzFA; see Fig. 1c) failure only inasmuch as the noises associated with each of the two stimuli in a pair are equal. It may well be that, depending on the particular Dual task under scrutiny, these noises change (with respect to the Single task).

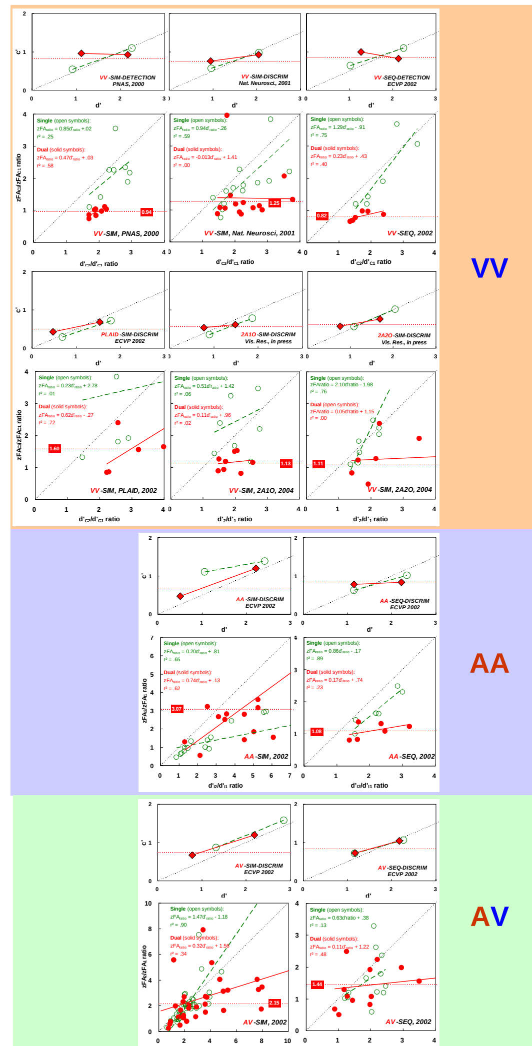

Figure 3. Data from 10 different experiments presented under the two formats described in Fig. 1c for Single (green symbols and lines) and Dual (red symbols and lines) tasks with paired Visual-Visual, Audio-Audio and Audio-Visual stimulations presented either simultaneous (SIM) or in sequence (SEQ).

NGES OF DECISION CRITERION AND SENSITIVITY

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THE ATTENTIONAL LINK: EMPIRICAL APPROACH

A meta-analysis of all the data in Fig. 3 reveals a negative correlation between the sensitivity loss in the Dual (relative to the Single) conditions and the *uc* (as contrasted with the optimal behavior). A closer look reveals that most of the d'-drop in the D-tasks is observed for the lower sensitivity stimulus.

Figure 4 displays the zFA-ratio in the D-tasks as a function of the d'-ratio between the S and D conditions for the lower (4a) and higher (4b) d' stimuli. While the S-to-D d'-ratio for the higher sensitivity stimuli is practically constant and close to 1 (i.e. no d' drop in the D-task), it varies in-between about 1 and 2 for the lower sensitivity stimulus.

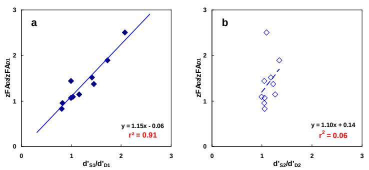

Figure 4. *zFA ratio* between high and low d' stimuli in the Dual task as a function of the *d' ratio* between Single and Dual conditions for the low (a) and for the high (b) d' stimuli. Comparison between (a) & (b) shows that zFA ratio in the D task is highly correlated with the d' drop in the D (relative to the S) task for the low (a) *but not* for the high (b) d' stimuli.

Fig. 4 points at a clear *relationship between the decision behavior (zFA) and the sensitivity loss in D-tasks*. As the latter is typically taken to represent the cost of *divided attention*, Fig. 4 demonstrates a straightforward **link** between ***attention* and *decision*** (Gorea & Sagi, 2004).

As already noted, the failure of the zFA equality in D-tasks (zFA_{D2}/zFA_{D1} ratios in-between 1 and 2.5) implies the ***uc* failure only under the equal noise assumption**. The possibility remains that if the relative noises associated with the low and high d' stimuli in the D-task are allowed to vary with respect to the noises in the S-task, the *uc* behavior may still be valid.

In the next section we follow this line of reasoning by (i) positing that *uc* **is** a pervasive behavior, (ii) allowing both the noises and the response gains for the low and high d' stimuli to vary in-between the S- and the D-tasks and (iii) checking the predictions of this modeling against the data.

THE ATTENTIONAL LINK: FORMAL APPROACH

Here we relax the equal-noise assumption and posit that (i) *uc* holds under all circumstances and that (ii) both the *internal responses*, R, and the *noises* in the S & D tasks are related by multiplicative factors α and β, respectively. We then test this model against the data.

Using the standard definition of d'

$$d' = \frac{R}{\sigma} \tag{1}$$

the relationship between sensitivities in the S (d'_S) & D (d'_D) tasks is given by

$$d'_D = \frac{\alpha R}{\beta\sigma} = \frac{\alpha}{\beta} d'_S \tag{2}$$

so that α/β is *the D/S sensitivity ratio*.

THE ATTENTIONAL LINK: FORMAL APPROACH – *sequel*

From eq. 2 and using subscripts 1 & 2 to denote conditions of *low* (d'≈1) and *high* (d'≈2) *sensitivity*, respectively (as used in all the studies of Figs 3 & 4), the *D/S sensitivity ratio of ratios* can be written as

$$\frac{d'_{D2}/d'_{S2}}{d'_{D1}/d'_{S1}} = \frac{\alpha_2/\beta_2}{\alpha_1/\beta_1} = \frac{\alpha_2}{\alpha_1}\frac{\beta_1}{\beta_2} \tag{3}$$

The measured zFA_i (i=1,2) is given by

$$zFA_i = \frac{R_{zFA_i}}{\beta_i \sigma_i} \tag{4}$$

Let's now assume that the *absolute criteria* [$R(zFA_{Di})=\sigma_{Di} zFA_{Di}$] assessed in the D task for the two stimulus levels (i=1,2), are equal:

$$R_{zFA_{D1}} = R_{zFA_{D2}} \tag{5}$$

On the assumption that noises in the S condition do not depend on stimulus level ($\sigma_{S1}=\sigma_{S2}=\sigma$), it follows from eqs 4 & 5 that the zFA_{Di}-ratio (in the D conditions) is

$$\frac{zFA_{D2}}{zFA_{D1}} = \frac{\beta_1}{\beta_2}$$
$$\Rightarrow zFA_{D2} = \frac{\beta_1}{\beta_2} zFA_{D1} \tag{6}$$

Substituting (6) in (3), yields

$$\frac{d'_{D2}/d'_{S2}}{d'_{D1}/d'_{S1}} = \frac{\alpha_2}{\alpha_1}\frac{zFA_{D2}}{zFA_{D1}}$$
$$\Rightarrow \frac{zFA_{D2}}{zFA_{D1}} = \frac{\alpha_1}{\alpha_2}\frac{d'_{D2}/d'_{S2}}{d'_{D1}/d'_{S1}} \tag{7}$$

Eq. 7 describes a ***linear relationship*** between the measured *zFA ratio* in the D-task and the measured *D/S sensitivity ratio of ratios*. Its **slope** stands for the *relative response gains for the low and high d' stimuli in the D-task*.

Testing the model against the data consists in checking this linear relationship in the empirical data. This is precisely the logic underlying **Figure 5**.

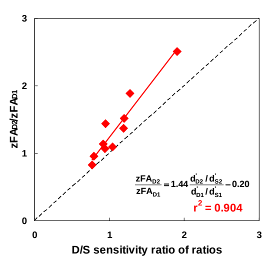

Figure 5. *zFA ratio* between high and low d' stimuli in the Dual task as a function of the *D/S sensitivity ratio of ratios* (see eq. 7). Note the high correlation (r^2 = .904) of the linear fit and its steeper 1.44 slope.

The obvious linearity of the empirical relation between the *zFA ratio* in the D-task and the measured *D/S sensitivity ratio of ratios* (Fig. 5) and the high correlation (.90) between these two indexes plead in favor of our model positing the equality of the absolute criteria in *all* D-tasks (eq. 5 and Sagi & Gorea, 2004). As such, they support the notion that the slope (α_1/α_2=1.44) of this function represents the relative response gains associated with the detection of the low and high sensitivity stimuli in the D-tasks. The data hence point to the fact that, in a Dual task**, *the higher d' stimulus is attenuated significantly more than the lower d' stimulus*.**

Because, *under the uc assumption*, zFA_{D2}/zFA_{D1} equals the relative internal noises associated with the low and high d' stimuli in the D-task (i.e. β_1/β_2; eq. 6), Fig. 4 points to the fact that *changes in the relative noises observed in the D-task are mostly due to the relative increase of the noise associated with the **lower d' stimulus***.

CONCLUSIONS

- On the assumption of a constant internal noise in Single and Dual tasks, the decision behavior in the latter shows ***criteria attraction*** effects ranging from the use of a ***unique criterion*** to a **quasi-optimal behavior** (in the SDT sense).
- The amount of *criteria attraction* correlates negatively with the d' drop in the D- relatively to the S-task.
- Inasmuch as the d' drop in a D-task is a consequence of ***distributed attention***, the data suggest a link between *criteria attraction* and *attention*.
- A model (i) allowing a change of both the response gains and the internal noises associated with each of the two stimuli in the D-task and (ii) posing that the *uc* is a generalized behavior in any D-task, provides a good fit to the data. The model implies that D-tasks differ from S-tasks in that the former yield:
  - A relative ***increase*** in the ***internal noise*** associated with the ***lower d' stimulus***;
  - A relative ***decrease*** in the ***response gain*** associated with the ***higher d' stimulus*.**
- By this model, a *d' drop* entailed by *distributed attention* can be thought of in terms of such gain and noise changes.

SPECULATION

The unbalanced noise and gain changes in Dual tasks for the high and low d' stimuli may reflect their asymmetric interference at the decision level and a larger suppressive signal exerted on the higher d' process to counterbalance its stronger interference with the lower d' process.

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