Modeling Pre-Attentive Visual Search in ACT-R

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By attempting to integrate and model Treisman's (1990), Wolfe's (1994), and Zelinsky's (1995) theories of visual search, we find unexplored areas of a cognitive architecture that can be improved by including a simple implementation of the visual pop-out effect. By introducing an initial implementation into the perceptual-motor component of ACT-R (Byrne, 2001), we create a formalization of pre-attentive visual search that effectively models current understanding and offers a number of new testable hypotheses.

Within visual search, there are a number of proposed theories that can be explored through models in a cognitive architecture, specifically those on pre-attentive selection. While the mechanisms of visual search are not fully understood (e.g., Hornof & Kieras, 1997), most researchers believe that there are two broad types of search: serial and parallel. Pre-attentive selection refers to a participant's ability—or lack thereof—to distinguish unique features of a stimulus previous to visually attending and processing that object.

Adding Pop-out to the Architecture

The pre-attentive theories of vision included in ACT-R/PM can be improved by discriminating between preattentively distinguishable objects and non-preattentively distinguishable objects. In order to account for these known affects, we add two parameters to the architecture to assess whether objects in the visual-field significantly distinguishes themselves based on their basic features. A simple example that we use is the difference between an 'X' and an 'O': Because current literature supports the idea of being able to preattentively distinguish unique features on the screen, we have added modifications to ACT-R (ACT-R/PM+PO) that assign a pop-out value to each object in the visual field.

Eq. 1 shows how this value for each stimulus increases with the product of both color and feature frequency in the numerator, and decreases as the square of the number of objects increases. This formula will be adaptable as more features are pre-attentively. Each basic feature that is added to this implementation of pop-out will be included as a multiplier of the numerator, and the denominator will simply be raised to the power of the number of features included.

$$1.\ \mathrm{Pop(Stim)} = 1 - \left(\frac{f(\mathrm{Stim}_{color}) \times f(\mathrm{Stim}_{feature})}{f(\text{Total-Stim})^2} \right)$$

Our formula has the added benefit of making the pop-out value of an object dependent on the number of distracters present. A higher number of distracters produce a more distinct pop-out value, which could be used by the architecture in the future to enhance ocularmotor fixation and movement to match Zelinsky's data.

Figure 1 shows a comparison of data to the current model, which appears to adequately model the pop out effect. ACT-R/PM+PO is a theory that can encourage further development of a more complete visual simulation system within a cognitive architecture.

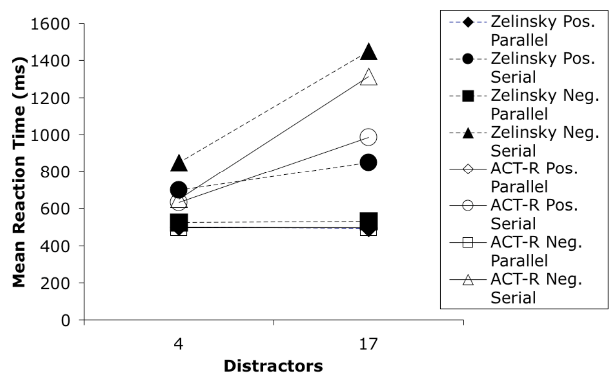

Figure 1. Pop-out (parallel) vs. conjunctive (serial) searches compared.

References

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought*. Mahweh, NJ: LEA.

Byrne, M. D. (2001). ACT-R/PM and menu selection: Applying a cognitive architecture to HCI. *IJHCS 55*, 41-84.

Treisman, A., & Sato, S. (1990). Conjunction search revisited. *JEP:HPP, 16*, 459-478.

Wolfe, J. M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bull. & Rev., 1*, 202-38.

Zelinsky, G., & Sheinberg, D. (1995). Why some search tasks take longer then others: Using Eye movements to redefine reaction times. *Eye Movement Res.*, 325-336.