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Visual Attention: The Multiple Ways in which History Shapes Selection

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The identity of the next thing you will attend to is under the control of several factors. One of these is your prior attentional history. New research shows that this 'selection history' comes in more than one distinct form.

The world delivers more stimulation to our senses than we can handle. Selectively attending to some stimuli and not others is one way to address this problem; but what should be selected next? Several different factors govern selection of the next object of attention. When you first look at Figure 1, your attention is probably drawn to the stop sign. It is highly salient and attracts attention in a 'bottom-up' stimulus-driven manner [1,2]. Fortunately, we are not slaves to stimulus salience. If I suggest that you attend to purple "C", you can direct your attention to a C in a 'top-down', user-driven manner [3]. In the 1990s, it was possible to argue that guidance of attention could be accounted for by these top-down and bottom-up forces [4].

It subsequently became clear, however, that 'selection history' is a force in its own right. You can get some feeling for the role of selection history by noticing that, once you have selected purple C, the other purple Cs in the display suddenly seem to pull at your attention in a way that they did not before. You have been 'primed' to direct your attention to purple Cs [5,6]. This is not really top-down because you, the user, did not specifically choose to become more aware of purple Cs; nor is it bottom-up, because the purple Cs are no more salient than before. Thus, in an influential 2012 paper, Awh, Belopolsky, and Theeuwes [7] declared that "Top-down versus bottom-up attentional control" was "a failed theoretical dichotomy". They added selection history to the mix. Now, in work reported in this issue of *Current Biology*, Kim and Anderson [8] provide convincing evidence that the selection history box needs to be subdivided.

Kim and Anderson [8] carried out a pair of experiments in which rather similar selection histories lead to different effects. In both experiments, observers were trained to make 'anti-saccades'. A saccade is a ballistic eye movement from point A to point B. Under normal circumstances, you make saccades to stimuli of interest in the visual field. In an anti-saccade task, you are instructed to look *away* from a target. Thus, in the first Kim and Anderson [8] experiment, observers were asked to look away from a colored square. The color varied from trial to trial and informed the observer of how valuable the current trial would be. If you successfully moved your eyes away from a square of one color, for example red, you were rewarded with 15 cents. If the square was blue, the same eye movement was worth nothing; sorry.

Observers completed several blocks of training and then they did a second task. A circle and a square appeared. You just needed to look at the circle. The shapes could be red, blue, or green (a color not used in training at all), but color had no meaning now. You just had to look at the circle. Nevertheless, if the circle had that valuable, red color, the eyes got to the target a bit faster. If the square was red, the eyes got to the circle a bit more slowly, as if you were attracted to the square, simply because it held the valuable color. Observers also mistakenly looked at the square more often if it had the valuable

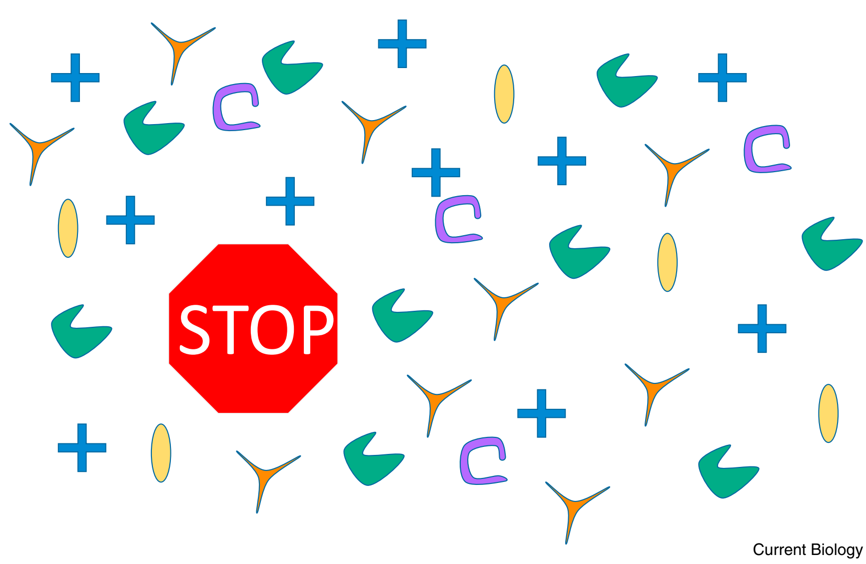

Figure 1. What guides your attention.
The stop sign grabs your attention in a 'bottom-up' stimulus driven manner. If you look for a vertical yellow oval, you are using 'top-down' user-driven attentional guidance. Your history of selecting one or the other of these stimuli also guides attention. For example, if you were given $5 for finding blue plus signs, you would continue to attend to blue plus signs, even if the rewards stop. The new paper of Kim and Anderson [8] shows that there is more than one type of 'selection history' effect.

color. Thus, a selection history that gave value to the color red caused red to attract attention, even when that worked against your current goals.

Now let us do, more or less, the same experiment with a slight wrinkle. Observers are trained to look away from the square. Squares can be red or blue. There is no difference in the value of red *versus* blue, but red squares are much more common than blue. As a result, you are trained to look away from red more vigorously than you are trained to look away from blue. In the next phase of the experiment, again you see a circle and a square and you must look at the circle. Now, you are a bit *slower* to look at a red circle. You have developed a habit of looking away from red and, even when that habit acts against your current interests, you cannot help hesitating just a bit before looking at the red circle. Thus, the same history of looking away from red squares produces opposite effects in the two experiments.

As Kim and Anderson [8] conclude, this means that selection history includes more than one way of guiding attention. Their experiments show guidance by value and something like motor habits. To that, we should add feature priming — the purple C effect described above. If you search for purple on one trial, you will be faster to search again for purple on the next. Together with top-down and bottom-up guidance, these three effects of selection history give us five ways to influence the deployment of attention. For the sake of completeness, let us add one more: you are guided by your knowledge of the world [9,10]. If you are looking for your cat, you may look in many places but, unless you have an odd cat, you will not look on the ceiling or in the toilet. Your cat expertise tells you that those are very unlikely spots. Actually, this 'scene guidance' can be subdivided into guidance based on where items are physically impossible (ceiling) and based on where they are physically possible but unlikely (toilet) [11,12].

Why should we care about the multiple processes that guide attention? Beyond the desire to understand a fundamental process of human cognition, we rely on experts to pay attention to critical items from suspicious masses in mammograms to suspicious objects in carry-on baggage. If we could design these artificial tasks so that the expert's attention was directed to the right spots, we could be safer and healthier.

REFERENCES

1. Nothdurft, H.-C. (1993). Saliency effects across dimensions in visual search. Vis. Res. *33*, 839–844.
2. Koehler, K., Guo, F., Zhang, S., and Eckstein, M.P. (2014). What do saliency models predict? J. Vis. *14*, 14. https://doi.org/10.1167/14.3.14.
3. Egeth, H. (1977). Attention and preattention. In The Psychology of Learning and Motivation, *Volume 11*, G.H. Bower, ed. (New York: Academic Press), pp. 277–320.
4. Wolfe, J.M. (1994). Guided Search 2.0: A revised model of visual search. Psychon. Bull. Rev. *1*, 202–238.
5. Maljkovic, V., and Nakayama, K. (1994). Priming of popout: I. Role of features. Mem. Cogn. *22*, 657–672.
6. Theeuwes, J. (2018). Visual Selection: Usually fast and automatic; seldom slow and volitional. J. Cogn. *1*, 29.
7. Awh, E., Belopolsky, A.V., and Theeuwes, J. (2012). Top-down versus bottom-up attentional control: a failed theoretical dichotomy. Trends Cogn. Sci. *16*, 437–443.
8. Kim, H., and Anderson, B.A. (2019). Dissociable components of experience-driven attention. Curr. Biol. *29*, 841–845.
9. Henderson, J.M., and Ferreira, F. (2004). Scene perception for psycholinguists. In The Interface of Language, Vision, and Action: Eye Movements and the Visual World, J.M. Henderson, and F. Ferreira, eds. (New York: Psychology Press), pp. 1–58.
10. Biederman, I., Glass, A.L., and Stacy, E.W. (1973). Searching for objects in real-world scenes. J. Exp. Psychol. *97*, 22–27.
11. Vo, M.L.H., and Henderson, J.M. (2009). Does gravity matter? Effects of semantic and syntactic inconsistencies on the allocation of attention during scene perception. J. Vis. *9*, 1–15.
12. Vo, M.L., and Wolfe, J.M. (2013). Differential ERP signatures elicited by semantic and syntactic processing in scenes. Psychol. Sci. *24*, 1816–1823.

Chromosome Segregation: Poor Supervision in the Early Stage of Life

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Abnormal chromosome number, or aneuploidy, is common in early mammalian embryos, although the underlying cell biological basis is still incompletely understood. New research reveals that cells often fail to wait for all chromosomes to properly attach to the spindle machinery before segregation, explaining why early embryonic cell cycles are so error-prone.

Cells have evolved sophisticated systems to segregate chromosomes equally between daughter cells during mitosis and meiosis. However, at least two mammalian cell types frequently fail to do so: oocytes and early embryonic cells [1,2]. This error-prone nature is counter-intuitive because cell divisions in oocytes and embryos would seem to be among the most important for reproductive fitness. The major safeguard for chromosome segregation is the spindle assembly checkpoint (SAC), which emits 'wait' signals that delay anaphase onset until all chromosomes are properly attached to the segregation machinery — the spindle [3]. Defective SAC signaling leads to

