A Neurocomputational Model of Anticipation and Sustained Inattentional Blindness

Anthony F. Morse, Robert Lowe & Tom Ziemke

SCAI Lab, School of Humanities and Informatics, University of Skövde
SE-541 28 Skövde, Sweden {anthony.morse, robert.lowe, tom.ziemke}@his.se

Abstract. Anticipation and prediction have been identified as key functions of many brain areas facilitating recognition, perception, and planning. In this paper we present a neurocomputational model in which feedback, effectively predicting or anticipating task-relevant features, leads to sustained inattentional blindness. A psychological experiment on sustained inattentional blindness in human subjects is simulated/replicated to provide visual input to an Echo State Network with separate readouts trained to track the attended object and detect the unexpected object. Feedback from the tracking readouts, is then used to simulate engagement in the task, and compared to results obtained without feedback, simulating passive observation. We find a highly significant effect of feedback, enhancing performance at the task and simultaneously degrading detection of unexpected features, thereby modeling the sustained inattentional blindness effect. We therefore suggest that anticipatory / predictive mechanisms are responsible for inattentional blindness.

Keywords: Enaction, Anticipation, Prediction, Neurocomputation, Reservoir Systems, Association, Inattetnional Blindness

1 Sustained Inattentional Blindness

Our perception of the world around us is subject to manipulation, even to the extent that we can be experientially blind to highly salient and temporally extended events. We can even be unaware of things we are looking directly at. Simons and Chabris (1999) note that “we perceive and remember only those objects and details that receive focused attention.” p. 1059. Though it is not entirely clear in this context what attention is, similar claims have been made by many researchers e.g. (Noë, 2004; O'Regan & Noë, 2001; Rensink, O'Regan, & Clark, 1997). This effect is demonstrated most startlingly in an experiment on sustained inattentional blindness by Simons and Chabris (1999) in which human subjects watch a video showing two intermingled groups of people, one dressed in white and the other in black, each passing a basketball between members of their own group. Subjects are asked to count how many times the ball is passed by one particular group (either those dressed in white or those dressed in black depending on which condition the subject is in). Somewhat surprisingly, many “observers fail to notice an ongoing and highly salient but unexpected event…[a] Gorilla walked from right to left into the live basketball passing event, stopped in the middle of the players as the action continued all around it, turned to face the camera, thumped its chest, and then resumed walking across the screen" p. 1069. Observers in this study "were consistently surprised when they viewed the display a second time, some even exclaiming, 'I missed *that*!?' " p. 1072. In this, and other psychological experiments, the effect of similarity between the attended (the team the subject is watching), distracter (the other team) and unexpected objects (the gorilla) has been systematically varied showing that close similarity between the attended and unexpected objects reduces the occurrence of inattentional blindness (Koivisto & Revonsuo, 2008; Most, Scholl, Clifford, & Simons, 2005; Most et al., 2001; Simons & Chabris, 1999). For example subjects attending to the team dressed in white where more likely to miss the black-haired gorilla than subjects attending to the team dressed in black. Most et al (2001) vary the luminance of the attended and unexpected objects showing that increasing similarity (in terms of luminance) decreases the likelihood of failing to detect the unexpected object. In a different task Koivisto and Revonsuo (2008) ask subjects to count how many times balls of one color bounce of the edge of a computer screen, while balls of a different color also bounce around the screen (see **Figure 1** below). In this task the unexpected object appears on the left of the screen and travels across it until it exits on the right. Subjects engaged in the counting task often miss the unexpected object and thereby display sustained inattentional blindness. In a number of experiments Koivisto and Revonsuo (2008) systematically vary the number of distracter objects and their similarity to the attended objects showing that (a) distracter objects have little or no effect and that (b) sustained inattentional blindness can occur even in the absence of any distracters. For simplicity sake it is this scenario, with no distracters that we will focus on here.

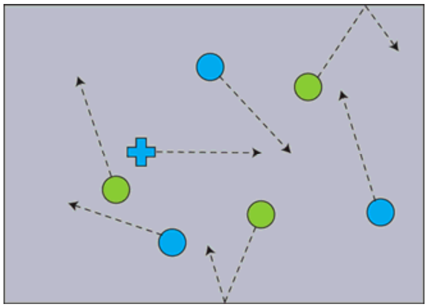

Figure 1 Illustration of Kivisto & Revonsuo's task. Human subjects count how many times the green (lighter) balls bounce, while ignoring the blue (darker) balls. The unexpected object, here a blue cross moves across the screen, often undetected.

2 Enactive Perception & Prediction

Increasingly cognitive scientists view prediction as central to cognition (Downing, 2007; Hawkins & Blakeslee, 2004; Noë, 2004; O'Regan & Noë, 2001; Thompson, 2007). The central claim of Noë's (2004) formulation of the enactive approach "is that our ability to perceive not only depends on, but is constituted by, our possession of… sensorimotor knowledge." p. 2, where sensorimotor knowledge "is implicit practical knowledge of the ways movement gives rise to changes in stimulation." p. 8. Prediction, the application of sensorimotor knowledge, is central to enactive theories of perception. Though Noë is careful to assert that sensorimotor knowledge is not for directing action, it is clear that the ability to predict would be extremely useful to any embodied agent interacting with a complex environment; for example, simulating or anticipating the effects of possible actions for evaluation in an agent-centered way e.g. (Clark & Grush, 1999; Grush, 2004; Hesslow, 2002).

All of this relies on the assumption that there are regularities of interaction, i.e. regularities in the ways that our actions mediate or change future sensory input. For Noë (2004) "the process of exploring the environment is mediated by [these] patterns of sensorimotor contingency" p. 103. Identifying these invariant relationships provides a means to recognize Gibsonian affordances (Gibson, 1979). For an enactive agent then, skilled action is practical knowledge, the mastery of which can be achieved through identifying the contextual regularities between actions and sensory data. Once recognized, these regularities become the basis of our perception of the world, as we predict how things will change as we interact with them.

From a neuroscience perspective Hawkins and Blakeslee (2004) suggest that "the cortex's core function is to make predictions" p. 113. Hawkins depiction of the hierarchy within the cortex highlights the interplay between low levels (i.e. regions of cortex close to sensory input such as area V1 in the visual cortex) responding to fast changing 'features' and higher levels (such as the inferotemporal or prefrontal cortex) responding to more invariant, larger scale, and slower changing things such as faces and objects. Top-down signals indicating expectations or predictions of which low level features will be active, not only fill in sensory gaps, but facilitate the high level response, and differentiate expected from unexpected bottom-up activity. Downing (2007) reviews neurocomputational models of various brain regions, all of which highlight the central role of prediction in brain function.

In combination these theories motivate the use of feedback from recognition predicting, priming, or just filling in gaps in the activity of lower level structures as a significant part of the perceptual process. We can therefore justify the use of feedback, from the tasks we are engaged in, in modeling perceptual phenomena such as sustained inattentional blindness.

The remainder of the paper presents a brief summary of neurocomputational difficulties and how we think organic brains solves them before providing details of our Neurocomputational model applied to a computational version of the experiment of Kivisto & Revonsuo just described. Our first experiment demonstrates that prediction enhances the normal performance of our model with the side effect of sustained inattentional blindness. In a second experiment we further vary the similarity between the attended object and the unexpected object and come to the somewhat surprising result/prediction that inattentional blindness is exaggerated as dissimilar unexpected targets become more similar to the attended object until their similarity is between 40% and 50%, beyond which the effect is reversed and, as one might expect, increased similarity reduces the effect of inattentional blindness. We are currently unaware of any human data confirming or refuting this finding/prediction. Finally we discuss the plausibility of our model and its implications both in explaining sustained inattentional blindness, and in understanding how organic brains work.

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