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09/23/04
9.00 T.A. Amy Perfors

Making Use of Peripheral Vision

The mechanics of human vision are central to our activity, yet are rarely considered as factors in our daily lives or competitive endeavors. In the case of peripheral vision, humans often do not even realize what they are lacking outside of their central vision, as we cannot focus on things outside of central vision because of the construction of the eye and the way our brain processes optical signals. Thus it is difficult to know how our range of peripheral vision is changing at any given time and how quickly we can react to stimuli outside of our central vision. Recent experimental research in these areas suggests that our visual field indeed “deforms” under stress, and that humans can be trained to react more quickly to stimuli in far peripheral vision. This research has many real applications in for example furthering our understanding of how athletes can use control and training of their peripheral vision to their advantage.

Central vision is vision of light caught by photoreceptors in the fovea, the central region of the retina. The fovea is very dense with cones (bright light receptor cells) and thus the perceived acuity, or detail, of objects whose image falls into the foveae of our eyes is very high. Outside of the fovea, rods (dim light receptor cells) become more prevalent, and acuity of objects falls greatly (Gleitman, 2004). We are never focused on objects in our far peripheral vision (otherwise we would have already focused them into our central vision) so we are generally unaware of how much we are missing outside of our central vision. Objects in motion are very noticeable out of the corner of the eye, but non- moving objects are easily ignored. Color sensitivity also drops greatly in the periphery.

A recent news release from the Max Planck Society describes experiments performed to determine precisely how color perception is carried out in peripheral areas. Quantitative study of the different red-green and blue- yellow color channels between the eyes and brain showed that peripheral ganglion cells, which transport information from all over the retina, are just as color sensitive as central cells, and the loss of chromatic (color) sensitivity originates in the brain (Max Planck Society, 2001). Our brain probably throws away extra color information in the periphery because it is simply useless and may lead to having too much data to process.

Other researchers have focused on how range of human vision changes under different situations. Rogers, Alderman, and Landers (2003) performed an experiment on 25 male high school varsity football team members to determine how peripheral vision is affected in a real- life stress situation. The experimenters measured each player's range of peripheral vision within an hour before practice to simulate a no- stress situation and within two hours before a football game to simulate a stress condition. Players were asked to press a buzzer when visual cues were detected in a domelike projection apparatus, and a scalar value representing the range of peripheral vision was calculated. In addition, the "hardiness" and recent level and negativeness of "life stress" of each player were measured through questionnaires each player completed before experimentation.

Rogers et al. found that baseline (non-stress) peripheral vision range was on average more than 20% greater than the range of vision in the stress situation (baseline range value 48.14 compared to stress value 39.87). Furthermore, under the stress condition, the range of vision of the 11 subjects measured to have highest hardiness was significantly higher than the range of the 11 subjects measured to have lowest hardiness (range value of 40.88 compared with 35.64). The researchers concluded that perceptual deficits occur in real-life stress situations like before a football game, and that these deficits were even greater than those in previous research that used lab-induced stress conditions.

But in what way exactly does our field of peripheral vision change? Roge, Kielbasa, and Muzet (2002) set out to measure deterioration of peripheral perception in different experimental conditions. Subjects were asked to perform a button-pressing task similar to that in Rogers et al. in response to stimuli in both central and peripheral vision. However, subjects were also instructed about which task to give priority to. Roge et al. then plotted the positions of the most peripheral signals perceived as the hour-long experiment progressed. They found that as the test was prolonged, the useful peripheral field deformed vertically (i.e., shrinkage occurred in the peripheral area close to the vertical axis.) Roge et al. deduced that this is due to lapse of the subject's vigilance.

The data also surprisingly suggested that when the peripheral task was given priority, the horizontal peripheral field actually decreased in a test of vigilance. Experimenters hypothesize that the useful visual field “deforms to conserve the individual's resources for detecting visual signals.” (Roge et al., 2002) They further compare the experimental situation with that of driving a car, where the driver is both controlling a complex central task and monitoring the periphery. Not only does the driver have to worry about all the traffic signs, billboards, and pedestrians, but he or she should apparently worry over worrying too much about these stimuli!

Reaction time for a stimulus outside of one's central vision is also important in daily life, and especially in auto driving and athletics. The team of Ando, Kida, and Oda at Kyoto University investigated human reaction times to stimuli in the peripheral field of vision and how practice of such tests can improve reaction time. The setup of their experiments are again similar to that of Rogers et al., but with a precise reaction- time measuring computer and muscle- movement detector that can measure both premotor (from stimulus onset to the appearance of the muscle action potential) and motor (from muscle electromyograph signal to the key press response) reaction time. Subjects were shown stimuli at the target of their vision (Central condition), 10% from center (Near Peripheral condition), and 30% from center (Far Peripheral condition). Half of the subjects practiced reacting to the stimuli in the Central condition while half practiced reacting in the Far Peripheral condition for a total of 1125 trials per subject over three weeks. Ando et al. found that the premotor reaction time for the peripheral visual field decreased with practice from a mean of 194.5 to 165 milliseconds, and that central reaction time decreased for both groups of subjects about an average of 10 msec. This means that the practice of reacting to peripheral signals carried over to quicker reaction times for central signals, and vice versa.

Furthermore, Ando et al. continued with this line of research and performed an identical experiment in 2004, and this time continued testing the subjects three weeks after the reaction- time practice was stopped. They found that the decrease in reaction time was retained by all subjects (Ando et al., 2004). The experiments suggest that the decrease in reaction time is caused by improvements to the neural correlates in the practice of responding quickly to the specific stimuli, and that these improvements are “remarkably stable” for at least three weeks.

If we imagine the world as a large collection of stimuli similar to those in Ando et al.'s experiments, daily interactions in life are similar to the “practice” performed during experimentation. This suggests that those who are constantly responding to things around them, like athletes or even drivers, will become better with repetition at the reaction task they are repeating. Another Ando et al. experiment provides a concrete example of this phenomenon. The same experimenters gave a similar reaction time test to a group of six male university soccer players and six nonathlete university students who had no experience of soccer or other ball sports training. This experiment added another set of trials where the stimulus would appear at a random position in the field of vision. Also, the stimulus would change randomly between a small, medium, or large ring. The premotor reaction times of the soccer players were significantly shorter than those of the nonathletes, with the difference ranging from about 10 msec for a small ring stimulus to about 7 for the large stimulus. What is interesting is that the total reaction time (premotor + motor times) was not very different between the groups, as the soccer players in some cases took longer on average in the motor reaction time (Ando et al., 2001). The researchers speculate the fast premotor reaction time is because the soccer players have either inherited the peripheral perceptual abilities to respond quickly or developed higher abilities than nonathletes. If we consider the results of all Ando et al. experiments , we can guess that the latter is the case; that in encountering many game situations requiring quick response times, soccer players develop the special ability to respond to things quickly under pressure.

But what of sports where the goal is to ignore the periphery, and instead devote as much attention as possible to tasks in the central vision? In professional golf, for instance, care is taken to quiet the onlooking gallery in order to present as little distraction as possible to the golfer. Professional golfers are often observed crouching down while reading putts, extending the brim of their caps with their hands, intently focusing only on the line of the putt. It would clearly be advantageous if the phenomenon of a shrinking horizontal field of view could be manifested to aid concentration in pressure situations where the central task is high-priority. Players of board games face a similar but more pure version of the issue, as vision provides the only connection between the brain and the game board, and full concentration on central vision, which presumably is occupied by the board, is absolutely critical.

Scrabble players face a unique problem in this respect. Not only must a player analyze the board and tiles on it in a given position, but he must also consider also his own rack, and the unplayed tiles in the bag. So where should a player be looking when choosing a play? After analyzing pictures from the 2004 National Scrabble Championships, it is clear that the better a player is, the more often the player has either the game board or his tile- tracking sheet in central vision, and not his rack of tiles. If the brain already shields out color acuity in the periphery and has the ability to contract the useful field of vision for some tasks, then it follows that it should be possible to intentionally restrict intense focus to objects in central vision and block out distractions, as top players of any sport demonstrate. However, lower- skilled Scrabble players, who are constantly searching for words in their rack of letters, face a problem: they cannot focus only on their central vision because that would exclude the board! We can thus conjecture that anagramming skill is the most important skill for a lower-skilled player to develop in order to improve Scrabble ability, so that more time can be spent looking at the board with full capacities to allow for strategizing.

Appendix

Division 1, Table 1, Day 2 of the 2004 National Scrabble Championship: [The players with best records in a division play each other at the lowest-numbered tables]

Notice that all expert players visible are either looking at the board or their tracking sheets. The author is in the front-right.

Division 7, Board 11: [division 7 is the lowest- skilled division]

Three of four people are looking at the tiles on their rack, and the other is apparently staring down her opponent.

Division 1, Boards 3 and 5:

Brian Cappelletto, widely considered the best head- to- head player in the world and the game's top strategist, is in the very rear of the photo shielding with his hands all peripheral field view in order to concentrate on the board. His opponent, Nathan Benedict, is smartly doing the same.

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[This is a news release based on the *Nature* article below]

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[Photo credits: Sherry St. John]

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