Ocular Dominance and Handedness in Golf Putting

Appendix 1: Overview of Historical Ocular Dominance Research

Roughly 60% of the population has been shown to be right handed, 30% left handed and 10% ambidextrous;\(^1\text{-}^5\) similarly approximately 67% of the population has been shown to have right eye dominance.\(^6\) Originally, researchers thought that ocular dominance was related to handedness or foot dominance, especially as in both handedness and ocular dominance, there seems to be a strong predisposition towards favouring the right side of the body. Researchers have now agreed that while handedness and foot dominance have been found to be highly correlated with each other, they are neither indicative nor predictive of ocular dominance.\(^7\text{-}^{10}\)

Hand and foot dominance are thought to be related to the dominance of one cerebral hemisphere in the brain, but ocular dominance cannot be created in this way. A semi-decussation of optic nerve fibres at the optic chiasm means that visual information from the right and left eyes are represented in both hemispheres.\(^7\text{-}^9\)

Despite a vast amount of time and effort that has been invested in understanding the physiological basis of ocular dominance and its functional roles, little agreement between researchers has been reached. Mapp et al. went so far as to suggest that the dominant eye determined by sighting ocular dominance tests, whereby the observer is asked to align a near target with a distant target, only exists because of the sighting dominance tests are designed so that only one eye may be used or because of the ease or the habit of using a particular eye for such tasks.\(^{11}\) On the other hand, Valle-Inclan et al. found strong enough evidence with their sensory dominance to test to conclude, at least under specific conditions, that there is a preference for one eye over during conscious attention tasks.\(^{12}\) Perhaps the only tenuous consensus amongst ocular dominance researchers has been that there are two, relatively distinct types of dominance: motor (or sighting) ocular dominance and sensory ocular
dominance. Traditionally, motor ocular dominance is measured through sighting and pointing tasks, and is thought to exist in situations where the individual is forced to choose between the two eyes (for example, sighting a rifle). Sensory ocular dominance is thought to be a more inherent process, associated with binocular rivalry in the processing of visual information.12, 13

Motor Ocular Dominance

Motor ocular dominance tests tend to create a forced choice situation, in which the only possible outcomes are right or left dominance. “No dominance” is assessed with these tests based on repetition; the more consistent an individual’s responses are, the stronger their dominance. The most commonly used motor ocular dominance tests are the “hole-in-card” test and the “pointing” test. The “hole-in-card” test requires that individuals hold a card with a small hole in it, directly in front of them with both hands and site a distant target through the hole with both eyes open. The individual is then asked to alternatively close their right and left eyes, without moving the card in their hands, to determine which eye sees the distant target. The eye which sees the distant target under monocular conditions is the dominant eye, and the eye which does not see the target is the non-dominant eye.14

The pointing test is similar to the hole-in-card test, except individuals are required to point with both index fingers (hands clasped together) at a distant target under binocular conditions. When the right and left eyes are closed alternatively, the eye which lines up with the pointed fingers is considered to be the dominant eye, while the eye that does not line up with the pointed fingers is considered to be the non-dominant eye.15

Other motor ocular dominance tests include asking people to look through the view finder of a camera held in both hands (the eye that they use is the dominant eye) and asking people to
make a small triangular hole between the index fingers and thumbs of their right and left hands, and look through the hole in their hands a distant target.

**Sensory Ocular Dominance**

Sensory ocular dominance is usually measured under binocular conditions, where a variety of responses are possible as individuals see either a unique image associated with either the right or left eye, or they see a combined percept of the two.\textsuperscript{12, 13} Some tests rely upon counting the number of responses (left, right or no dominance) to quantify the strength of the ocular dominance, while others measure a gradient of responses (strong right or left, weak right or left, no dominance). Gradient tests are usually conducted under stereoscopic conditions where two images are fused and the perception of the fused images determines the type and strength of the dominance.

Common clinical tests for sensory ocular dominance include the Worth 4 Dot and blur sensitivity. The Worth 4 Dot test, a common binocular fusion test, requires individuals look through a red filter with one eye and a green filter with the other, at a target of four dots. Three of the dots are either red or green, while the fourth dot is white; if an individual perceives the fourth dot as being red, the eye with the red filter would be the dominant eye (and vice versa for a green dot) but if the fourth dot was perceived as being a muddled yellow colour, there is no dominance as the red and green percepts contribute equally to perception.

Blur sensitivity tests are often conducted when fitting presbyopic contact lens corrections. Under binocular conditions, plus lenses (+0.25D, +0.50D, +1.00D) are alternately added to the right and left eye distance refractive corrections. The eye in which the blur is less noticeable and binocular visual acuity is less affected is considered to be the non-dominant eye.
Motor versus Sensory Ocular Dominance

There is a lack of consensus in ocular dominance research resulting from a lack of consistency in how ocular dominance is measured.\textsuperscript{14, 16-18} Measures of sensory and motor dominance do not agree well with each other, although individuals with strong ocular dominance tend to give more consistent results across tests.\textsuperscript{8} Studies which have tried to measure the strength of individuals' ocular dominance have found that the vast majority of individuals seem to have a weak ocular dominance (61%). It has been suggested that this is a reason for the decreased reliability of motor ocular dominance (sighting dominance tests), and may be a contributing factor to the disagreement between different dominance measures.\textsuperscript{13}
Appendix 2: Visual Task Analysis in Golf

If one considers the specific strokes used in golf, these include drives off the tee box, iron shots on fairways, chips and wedge shots out of bunkers and sand traps, and putts, used on the putting green. Putts account for approximately 43% of the shots taken in golf game,\textsuperscript{19} despite putting greens comprising only a small proportion (approximately 2%) of the total course area.\textsuperscript{20} For these reasons, putting is often considered to be one of the most important aspects of a golf game. It is often considered to be one of the most difficult as well.\textsuperscript{19}

Visually, putting is a very complex task due to its unpredictable nature and the accuracy and precision required for success. The visual requirements of putting can be broken down into three principle elements, each distinguished by the demands placed on the visual system. These three elements are green reading, alignment, and the putting action phase.

Green reading is the most visually complicated of the putting elements, although arguably it is also the skill that requires as much natural talent as technical expertise. Green reading requires accurate judgment of the distance of the ball from the hole, judging the amount of friction the grass will exert on the ball, reading the contours of the green to determine how the ball will break, and understanding how the type and cut of the grass, the time of day, the lighting and the weather will affect the path and speed of the ball once it is hit, not to mention the unpredictable effect of footprints left by other players earlier on the green.

The purpose of green reading is to perceive how the conditions listed above will affect the path of the ball, and to choose a line or a direction to hit the ball, which compensates for the conditions at hand. In choosing a line, golfers must decide on a target to aim towards, which is, more often than not, a blade of grass or a unique feature of the green rather than the actual hole. The hole is rarely chosen as the target of the aim line, because most putting greens are
not flat and golfers must aim towards a point that compensates for the slope and speed conditions of the green instead.

In terms of vision, green reading demands the use of stereopsis and colour contrast sensitivity, both of which are affected by a player’s visual acuity and colour vision. Stereopsis is important for judging the distance between the ball and the hole, and colour perception and contrast sensitivity are important for perceiving the contours of the green.

Alignment in putting consists of two discrete visual tasks that are dependent upon each other. The first of these tasks is aligning the ball with the aim line of the putt; the second is aligning the club with the ball prior to the start of the swing. Aligning the club with the ball actually takes place in the putting-action phase (defined below), but it is discussed in conjunction with ball alignment because they are similar vision tasks. An alignment error in either or both of these tasks usually results in a missed putt. From a vision perspective, both of these tasks are highly dependent on making accurate Vernier acuity judgments under binocular conditions.\textsuperscript{21, 22}

The majority of alignment research in golf has concentrated on the alignment of the club with the ball, and particular emphasis has been placed on swing mechanics. Pioneering work in this area by Pelz found that angular alignment (face angle) determined 83\% of the initial direction of the putt, whereas horizontal alignment (putter path) accounted for a mere 17\% of the putt direction.\textsuperscript{19}

Typically, golfers walk around the putting green when reading it and then position themselves behind the ball when aligning it. Therefore, when addressing the ball, golfers need only align their club with the ball and hit a straight putt. In aligning the club and the ball, many golfers (professionals included) use the logo on the ball or a straight line as a guideline that can be
aligned with both the aim line and the markings on the club. In fact, Van Lier, Van der Kamp and Savelsbergh advocate for the importance of reading the green and using the ball logo as an alignment aid to help overcome the distortions in perceived direction.\textsuperscript{23}

When using a guideline on the ball, alignment of the club and the ball essentially becomes a Vernier acuity task. Recent research by Guillon \textit{et al.} supports the use of an alignment guideline, and has found that in terms of horizontal alignment, individuals are actually capable of making finer judgments of alignment than is needed for accurate horizontal club alignment.\textsuperscript{24} With respect to angular alignment judgments though, individuals were not as successful. In a study of 25 individuals, who were not golfers, the average angular alignment that could be detected was 0.6°, which on a 12 foot (3.66m) putt was equal to a 31.8mm error.\textsuperscript{24} Considering a golf ball must not be less than 42.67mm in diameter\textsuperscript{25} this is a significant alignment error which would result in a missed putt.\textsuperscript{24}

Alignment judgments have been shown to be more accurate when made monocularly, as monocular judgments do not suffer from the same parallax errors that affect binocular judgments. Unlike traditional Vernier acuity studies where alignment judgments are made under monocular conditions, judgments of alignment in golf are made under binocular conditions. Ocular dominance provides a unique avenue for the creation of monocular-type conditions in a binocular environment and has the potential to be beneficial for putting success.\textsuperscript{21, 22}

The putting action phase is the portion of the putt that starts when a golfer addresses the ball with the putter, and ends when the ball has left the putter after contact. This phase is the biomechanical-action phase of the putt, and has attracted the attention of players, coaches and researchers alike, as it is believed to significantly influence performance. During this phase that the club is lined up with the ball, the backswing is taken and the ball is struck with a
predetermined amount of force to start the ball moving in the direction of the hole. With the highest motor demand of the three putt phases, the putting action phase is highly susceptible to external and internal distracters, including stress. From a vision perspective, the putting action phase relies on Vernier acuity, ocular dominance and gaze behaviour control (i.e. fixation stability) aspects of the visual system.

REFERENCES


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