Perception, 2003, volume 32, pages 1151 – 1154

DOI:10.1068/p5056

Last but not least

Golfers may have to overcome a persistent visuospatial illusion

The perceptual world does not conform to the conventions of abstract three-dimensional Euclidean space. Perceptual measurements of the geometrical property of alignment of a pointer with a target demonstrate a persistent visual illusion, which is resistant to extended practice. In golf, as in some other sports, players have to align the path of their swing through the ball with a distant target. To do this they must make a judgment about the intersection of a line in space and a point. However, judgments of geometrical properties in physical three-dimensional space are notoriously unreliable (Blank 1953; Cuijpers et al 2000; Indow 1991; Kelly et al, in press; Koenderink and van Doorn 1998; Koenderink et al 2000; Luneberg 1947). Koenderink et al have shown that, if a pointer on one corner of an equilateral triangle is aligned with an adjacent corner (observer in the centre of the triangle), the angles are overestimated for small triangles and underestimated for large triangles (greater than 10 m viewing distance). We used a similar exocentric pointing task to measure alignment errors in golfers, and found a systematic perceptual error that appeared unaffected by expertise. This illusion did not translate into bias within a perceptually guided motor task, namely putting.

An exocentric pointing task utilises a pointing device and a target placed strategically in physical space, and contrasts with an egocentric pointing task, such as sighting a gun, where the path to the target from the eye is aligned through the pointer. We investigated whether golfers were subject to an exocentric pointing illusion by asking them to make judgments about the alignment of a pointer and a target. A schematic diagram showing the experimental apparatus is shown in figure 1. Subjects judged whether a pointer was aimed at a target from the positions—behind, parallel on the left, and parallel on the right—of the line joining the pointer and the target. The distance between pointer and target was 2 m. The pointer comprised a short white bar, which was mounted above a circular black card. The purpose of the latter was to

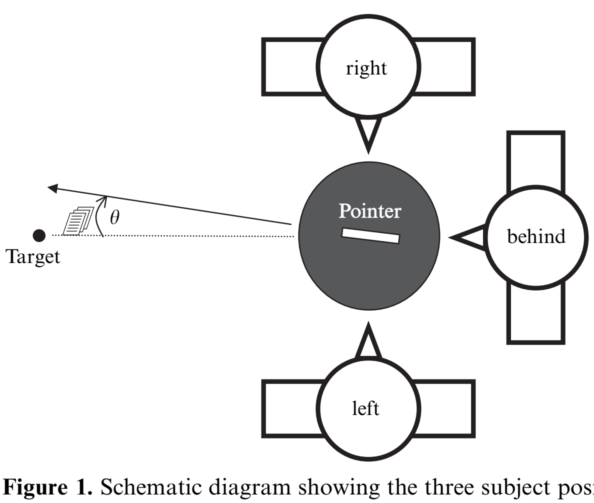

Figure 1. Schematic diagram showing the three subject positions (left, right, and behind) in relation to the pointer. The pointer was a plastic tube, 7.8 cm long and 1 cm in diameter, mounted on a spindle that protruded 5 cm above the centre of a black cardboard circle of diameter 60 cm that hid the mechanism. This placed the pointer 15 cm above the floor. The viewing angle was 20°. The distance between pointer and target was 200 cm. Pointer orientation was controlled by a 0.9° stepper motor. Alignment was measured by an interleaved staircase procedure (see text).

mask the underlying computer-controlled stepping motor in order to stop subjects lining up the pointer with features on the apparatus.

Subjects reported whether the bar was pointing to the right or left of the target by pressing one of two mouse buttons. When the subject reported to the right, the pointer shifted leftwards on the next trial of that sequence until the subject changed his response. At these reversals, the size of the step was reduced. In order to prevent subjects making judgments based on pointer rotation relative to the position on the previous trial, the pointer rotated to a random orientation up to 60° to the right or left of the target between trials. This was constrained such that this random inter-trial position was always more than 30° away from the subsequent trial. Also, on 25% of trials the pointer rotated somewhere between 30° – 60° to the left or right of the target. Responses on these trials did not contribute to the staircase.

The alignment measure (θ) was the average of the first 5 turning points at the smallest step size available (0.9°) expressed in degrees of rotation clockwise from the target line (the notional line joining pointer and target). Each data point is the average of at least two interleaved sequences. Finally, we calculated the left-alignment error as the difference between the alignment measure in the left condition (θ_{left}) and the alignment measure in the behind condition (θ_{behind}). Similarly, right-alignment error was the difference between right-alignment and behind-alignment measures ($\theta_{\text{right}} - \theta_{\text{behind}}$).

These calculations ensured that any misalignment of the pointer by the experimenter did not introduce a constant error into the results. In point of fact, θ_{behind} did not differ from zero ($t_{14} = 0.57$, $p = 0.58$).

The fifteen subjects (one left-hander), all male golfers and members, staff, or visitors to Gatton Manor Golf Course, Surrey, UK, made systematic alignment errors. When subjects stood to the left (see figure 1), the pointer would generally have to be rotated slightly clockwise to appear to point at the target. Similarly, when subject stood to the right, the pointer would have to be rotated anticlockwise. The effect was robust, with a strongly significant difference between left-alignment and right-alignment errors [means were 1.25° and −1.56°, respectively ($t_{14} = 4.09$, $p = 0.001$)]. One can readily verify the effect by placing a pencil on the ground pointing at a target, then checking the alignment while standing to one side. The direction of the effect is consistent with the Koenderink et al (2000) result for exocentric judgments in the near field, although in their experiment viewing distance varied with target – pointer distance, and in our experiments the distance between the observer and pointer was fixed.

Correct alignment is one of the key elements in golf. We take the pointer angle to be a measure of the apparent spatial position of the target. Informal observations indicate that the same pointing illusion occurs for the pointer placed perpendicularly to the target. Thus the pointing illusion will, if uncorrected, lead to the clubface being placed 'open', which generates a slice, one of the most common faults of poor players, or a push to the right if the line of swing is also along the line of the illusion. An obvious question to ask is: Does performance relate to illusion size? In figure 2, left-alignment and right-alignment errors are plotted against handicap. There is no relationship between illusion size and golfing ability. Prolonged alignment practice does not decrease the illusion. The illusion size was statistically indistinguishable for alignment on the heavily practised side (left of target line for right-handers) compared to the unpractised side ($t_{14} = -0.44$, $p = 0.67$).

In many cases it was not possible to check official handicaps. We depended on accurate reporting by our subjects. However, handicap correlated with putting accuracy ($r = 0.45$, $t_{13} = 1.81$, $p = 0.047$), which we measured by asking subjects to putt 10 times at a target along a flat surface (carpet) from a distance of 2 m. They were asked to knock over the target. For misses, the distance from the target as the ball passed the target was recorded as it rolled over a strip of paper with distance marked off as a guide.

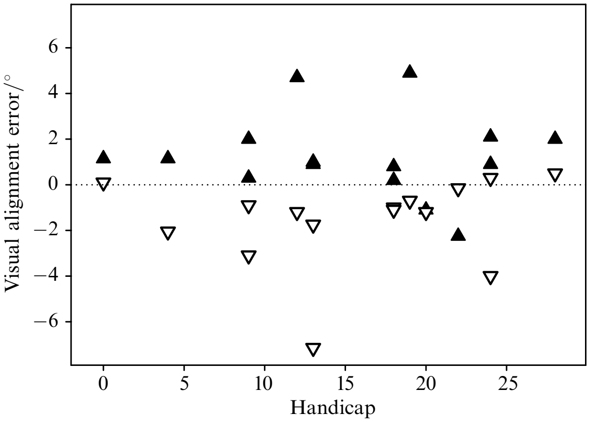

Figure 2. Left-alignment and right-alignment errors plotted against handicap.

Low handicappers were more accurate, demonstrating that the measures taken were reliable indicators of skill. Although there was a consistent error in pointer alignment, this did not correlate with the signed putting error (figure 3), and there was no evidence that signed putting error differed from zero [for this test, the sign of the putting error for the left-handed players was reversed ($t_{14} = 0.27$, $p = 0.79$)]. The lack of an illusion for putting could be due to a recalibration of perception (Bedford 1999) or the use of a privileged cortical pathway for perceptually guided motor control not subject to perceptual illusions (Carey 2001; Milner and Goodale 1995). However, we also found there is a strong correlation between putting variance and the magnitude of the alignment error on the unpractised side ($r^2 = 0.69$, $F_{13} = 28.5$, $p = 0.0001$), although no strong correlation between putting variance and alignment error magnitudes on the practised side ($r^2 = 0.01$, $F_{13} = 0.13$, $p = 0.72$). In other words, inconsistent putters tend to have a big illusion on their unpractised side. Inconsistency then may be a product of the additional adjustment to accommodate a large illusion. Since the size of the illusion does not differ between sides, the lack of correlation on the practised side suggests that some players have developed a strategy for compensating for their illusion, through practice in playing golf, which they then apply to the pointing task.

The difference between good and bad players may reflect the size of the illusion coupled with more or less successful strategies for reducing its effect. Golf professionals have well worn routines to help them establish accurate alignment including lining up while standing behind the ball then picking a 'short target' a foot or two ahead of the ball on the line to replace the real target. For such a strategy to be useful, one would expect to find a reduction in the effect as distance to the target shortens. Using our

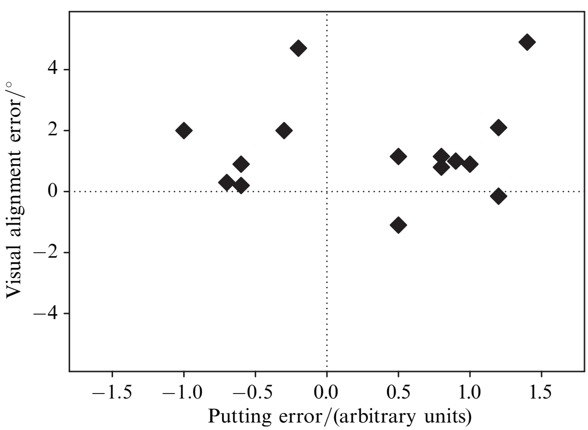

Figure 3. Visual alignment error plotted as a function of putting error. Note that the putting bias of the left-handed player is plotted against his right-alignment error whilst the putting bias of right-handed players is plotted against their left-alignment errors.

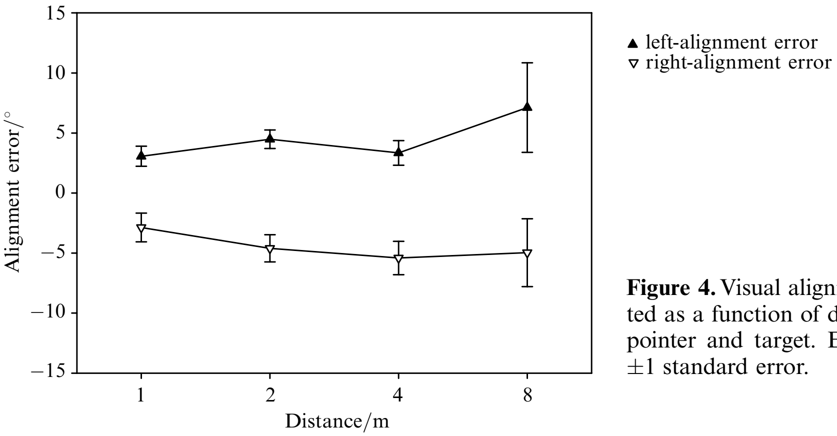

Figure 4. Visual alignment error plotted as a function of distance between pointer and target. Error bars show ±1 standard error.

exocentric pointing task we assessed the size of the illusion as a function of distance for eight subjects (only one of whom was a golfer). The procedure is as described above except that the subjects' scores are the mean of four staircases.

Left-alignment and right-alignment errors are plotted as a function of distance in figure 4. It is clear that there is no great reduction of the illusion as distance decreases. This implies that a golfing strategy involving putting along a line to a short target would be unsuccessful. It may be that the value of the short target is to reduce shoulder and head movement in aiming. Compensation in putting seems to be primarily motor learning and/or a willingness to consistently aim in a direction that generates the desired effect although it seems contrary to perception.

Alan Johnston (corresponding author)
Department of Psychology and Institute of Cognitive Neuroscience, University College London, Gower Street, London WC1E 6BT, UK; e-mail: a.johnston@ucl.ac.uk

Christopher P Benton
Department of Experimental Psychology, University of Bristol, 8 Woodland Road, Bristol BS8 1TN, UK; e-mail: chris.benton@bristol.ac.uk

Shin'ya Nishida
Human and Information Science Laboratory, NTT Communication Science Laboratories, NTT Corporation, 3-1, Morinosato-Wakamiya, Atsugi-shi, Kanagawa 243-0198, Japan; e-mail: nishida@brl.ntt.co.jp

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ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 32 2003

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