THE PERFORMANCE EFFECT OF A PHYSICAL GUIDANCE DEVICE ON THE LEAD-ARM IN GOLF

[A Preliminary Study]

Michael Middleton

**Simplified Sports, Orange, NSW, Australia*

Abstract

20 recreational, golfers and one professional, were tested to ascertain if a flexible, lead-arm guide had any effect on their accuracy and distance performances. As well, short-term post-use performance, pre-ball impact club delivery, and post-impact ball flight variables were measured. A number of positive performance results were indicated.

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In preparation for publication

1.0 INTRODUCTION

Creating an effective, reliable golf swing involves mastery over a complex movement pattern (Magill & Anderson, 2014), which for many, particularly 'recreational' golfers, can be both difficult and challenging in an ongoing way. In golf there is a need to control and maintain the high amount of variability possible within the number of 'degrees of freedom'[1](dof), 'levers' (Hay, 1993), or 'components' (Kelly, 2008) that are found in the basic swing movement-pattern. For example, within this overall swing pattern, both arms contribute a significant volume of 'arm-positional information' that needs to be processed (consciously and/or non-consciously) until the correct arm-sequencing is learnt and becomes automated (Abernethy et al, 1997; Magill & Anderson, 2014). To reduce aspects of the above complexity and the potential for confusion that some recreational golfers, in particular, face, one line of thought is for the lead-arm to remain relatively straight at key phases, without tension (Lumsden, 2015), and thereby act as part of the swing 'guide' (Rudy, 2004; Magill, 2012; Suttie, 2016).

From this reasoning, anything the golfer can undertake to reduce the variability in lead-arm mechanics could potentially help to improve their overall swing pattern performance. One instance of this would be learning to maintain an extended/almost straight arm as one 'dof', where the fully extended arm is deemed to be only 'one lever' during the swing. Whilst the vast majority of top golfers have developed this 'one dof' lead-arm control pattern (Rudy, 2004; Garcia, 2012) many novices are regularly observed with bent/flexed lead-arms (Furze, 2015; Iffland, 2015; Brackenridge, 2016). Accordingly if the lead arm is allowed to vary between one and two dof during the swing, this may cause the user, at speed**, to lose the integrity of the swing pattern and not achieve a satisfactory performance result (Abernethy et al, 1997; Furze, 2015). One way to address this situation is to improve feedback on the lead arm position so that more attention becomes available to address other swing pattern movements, including those of the 'following-arm' (Ward, 2015). ** N.B. Importance of golfer's 'speed' of movement here, to eventual ball flight.

Where the recreational golfer is concerned, feedback on the desired lead-arm position can be enhanced by 'augmented [or 'external'] feedback[2]', such as verbal information (eg praise) or through physical guidance devices (Magill, 2012; Lee & Schmidt, 2014, Magill & Anderson, 2014). The benefit of this type of physical guidance is that it could positively reinforce the desired movement pattern and shorten the 'learning time' to acquire an effective, more reliable swing-pattern. At the same time, conversely, there is a possibility that the learner could become, somewhat, overly dependent on the device and use the physical guidance as a 'crutch' (Schmidt et al, 1989).

When searching for ways to minimise performance errors that occur because of swing-pattern control problems, players often work with a coach who can direct attention to a specific movement-pattern problem. Alternatively they can apply a 'self-help' approach and choose from a myriad of training and guidance aids available to them. One recent golf training aid identified is a flexible, lead-arm guide (F.L.A.G), which is designed to help position and reinforce the user's lead-arm posture during critical phases of the swing, particularly the backswing and downswing. The guide is unique in allowing the lead-arm to bend during the final 'follow through/folding' phase of the swing-pattern. The expectation as noted earlier, is that this 'guided-learning' will reduce the amount of conscious attention the user needs to apply to their lead-arm. This should quicken the 'learning-process' while at the same time allow for more attention to be focused on the following–arm and other critical components of their swing-pattern.

Accordingly, this preliminary study was developed to test the hypothesis that the aforementioned F.L.A.G would have a positive effect on a golfer's immediate and short-term, post-use performances.

[1]*Degrees of Freedom defines the number of independent elements or components in a control system and the number of ways each component can vary (Magill & Anderson, 2014). Each element can vary in a number of ways, independently. In golf there are deemed to be two degrees of freedom in the flexed arm – the forearm by itself (and pivoting around the elbow joint), and the upper arm; or one degree of freedom when the above two parts are maintained in a fully-extended (or close to fully extended) position.*

[2]*Augmented feedback – A generic term used to describe information about performing a skill that is added to sensory feedback and comes from a source external to the person performing the skill. It is sometimes referred to as extrinsic or external feedback (Magill & Anderson, 2014).*

2.0 METHOD

Participants: 20 recreational, right-handed male golfers, and one, right-handed male professional golfer. Age range: 23 to 79 years ($\bar{x}$ = 61, SD ± 12). Handicap range: 0 to 28 ($\bar{x}$ = 14.8, S.D. ± 5.7), indicating a range between highly skilled and moderately skilled players.

Apparatus

To collect data from pelvis and torso segments, as well as measures of the subjects' club delivery and associated ball flight variables, the Walkabout advanced motion measurement (AMU) system and 'TrackMan 2 - Performance Studio 3.1' were used.

Procedure

The initial testing was conducted at practice ranges in Melbourne, VIC and then Orange, NSW, Australia. Subjects used their preferred 7-Iron to hit Titleist ProV1 golf balls from an artificial-grass (astroturf) surface towards a set target, and were asked to use their natural, everyday swing during the testing.

Each participant was randomly allocated to one of the following test patterns:

i. hit 5 practice (but tested) balls without the lead-arm guide on; then hit 20 test balls with the guide on; then remove the guide and hit 20 test balls without the guide; or

ii. hit 20 test balls without the guide; then hit 5 practice (non-test) balls with the guide on to gain a feel for the device, before hitting 20 test balls with the guide on; then without the guide on, hit another 5 test balls.

Performance Measures

(a) associated post-use, short-term performance effects – determined by measuring the immediate difference in performance, after the guide was used, compared to before it was used;
(b) swing pattern – analysis of any perceived/anecdotal changes the guide may have had on selected club delivery and ball launch parameters; and
(c) 3D Measures of thorax, pelvis and lead-arm movements of the professional subject.

Data Analysis

For each subject, the average values and standard deviations for all variables across both conditions were calculated via custom software. Results were exported to Microsoft Excel for further analysis.

All variables were examined for individual responses at 99%, 98%, 95%, and 90% confidence intervals. For all variables, the number of subjects who had potentially significant differences between means was calculated. Other aspects of the Data Analysis are listed in Appendix 1.

Performance responders were identified by calculating the z-score of the post-guide results to the pre-guide results (z-score = [post-guide average – pre-guide average]/pre-guide z score). A z score of over 0.5 was classed as a moderate responder. A z-score of over 1 was classed as a strong responder.

3.0 RESULTS & DISCUSSION

The initial focus for this study was designed to ascertain if the described coaching aid had positive performance effects on the participants' 'accuracy' and 'distance' performances. Further conversation then added questions about whether the guide would positively affect club delivery, ball flight variables, and body-swing-pattern variables of users, if at all.

The results from the research, seeking answers to the above questions are described below, as:

3.1 the difference in effect the device had on subjects' accuracy and distance measures, after it had been used, compared to before it was used;

3.2 what effects the guide had on Club Delivery (pre-ball impact) , and Ball Flight (post impact) variables; and

3.3 using the only professional golfer in the group, an assessment of what effects the guide was perceived to have on swing-related, body movement factors, deemed important in the golfer's overall swing-movement pattern;

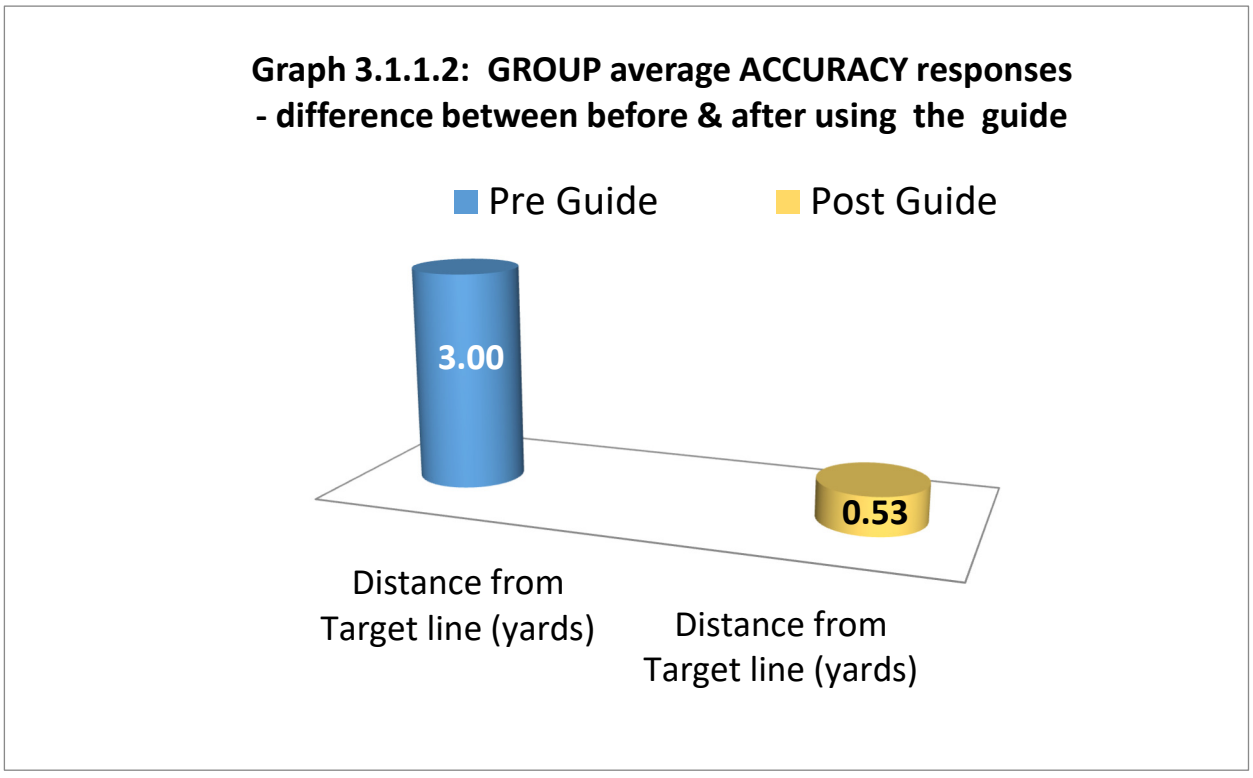
Some positive performance effects were indicated.

3.1 SHORT-TERM, POST-GUIDE EFFECT ON ACCURACY and DISTANCE

TABLE 3.1.1: Group Ball Carry AVERAGES – difference between pre-use and post-use of the guide.

Distances in yards	Pre-Guide	Post-Guide	Difference
3.1.1.1 Distance ball landed from Target Line - **Accuracy**	3.00	0.53	-2.47*
3.1.1.2 Distance ball travelled after impact - **Distance**	115.5	119.40	3.90

From Table 3.1.1: There was a small, average increase in accuracy* (side) of almost 2.5 yards, and 'distance'(carry) of 3.90 yards, between pre-guide to post-guide tests.



Graph 3.1.1.2: There was an average increase in accuracy of just on 2.50 yards between before the guide was used, and after it had been used, meaning, on average, balls finished closer to the set target line.

TABLE 3.1.1.1: ACCURACY – Ball Carry AVERAGES: Difference between 'before guide use' and 'after guide use'.

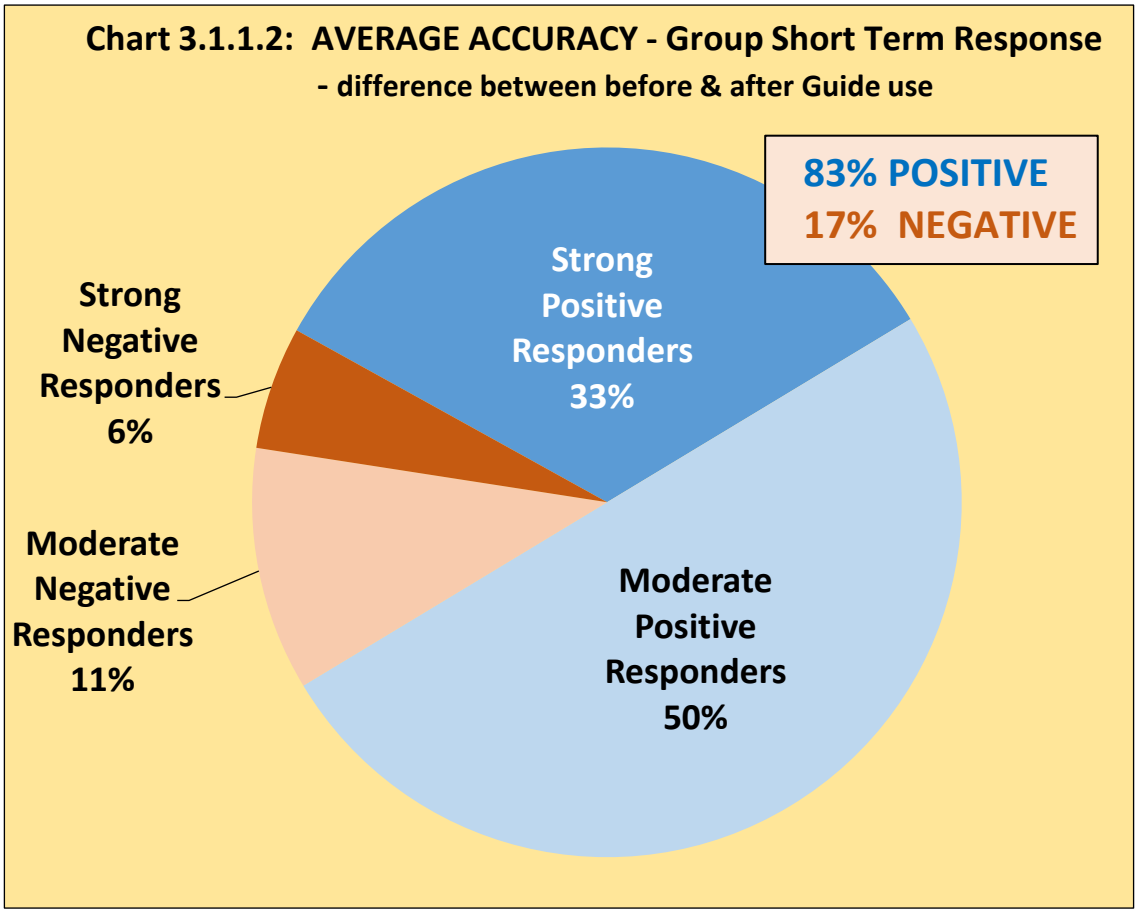
	Pre-Guide	Post-Guide	% Diff	Difference
Distance to Target Line – Accuracy **Average of St Dev**	6.034	6.127	9.28%	0.015

Table 3.1.1.2: The Average of Standard Deviations suggests that there is no significant difference between the pre and post guide as to the 'tightness' of the accuracy cluster across the test group.

TABLE 3.1.1.2: Group average ACCURACY responses - difference between pre & post guide use

ACCURACY	Responders
Strong Positive Responders (Closer to Target Line)	6
Moderate Positive Responders (Closer to Target Line)	9
Moderate Negative Responders (Further from Target Line)	2
Strong Negative Responders (Further from Target Line)	1

Table 3.1.1.2: There were considerably more participants who responded positively in terms of shot accuracy, with one third of the group demonstrating a strong response and a half the group demonstrating a moderate response. Of the 2 moderate negative responders, both offset the moderate negative response with a positive distance response (in other words, they were less accurate but hit longer). Conversely, only 2 of the 9 moderate positive responders to accuracy also reduced their distance. A visual representation of Table 3.1.1.2 is shown in Chart 3.1.1.2, below.



'Responders' shown in Table 3.1.1.2 have been grouped as either 'positive' or 'negative' in Chart 3.1.1.2 above, viz 83% or 17%.

Chart 3.1.1: Group average ball carry DISTANCES
- difference between pre & post guide use

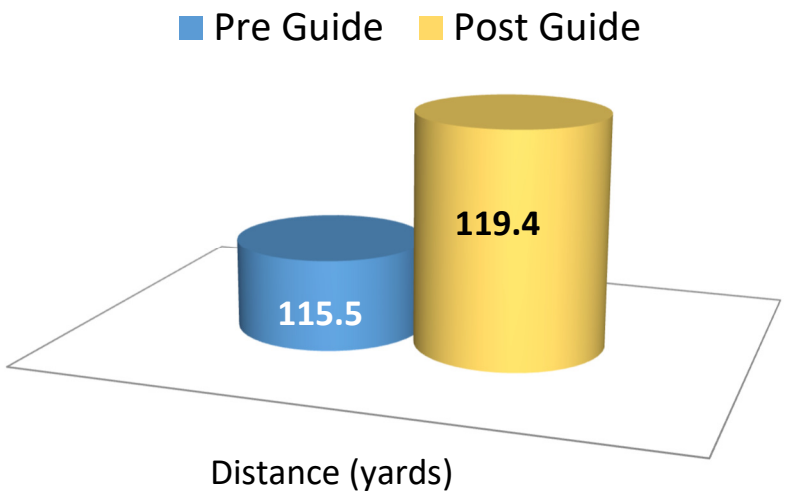


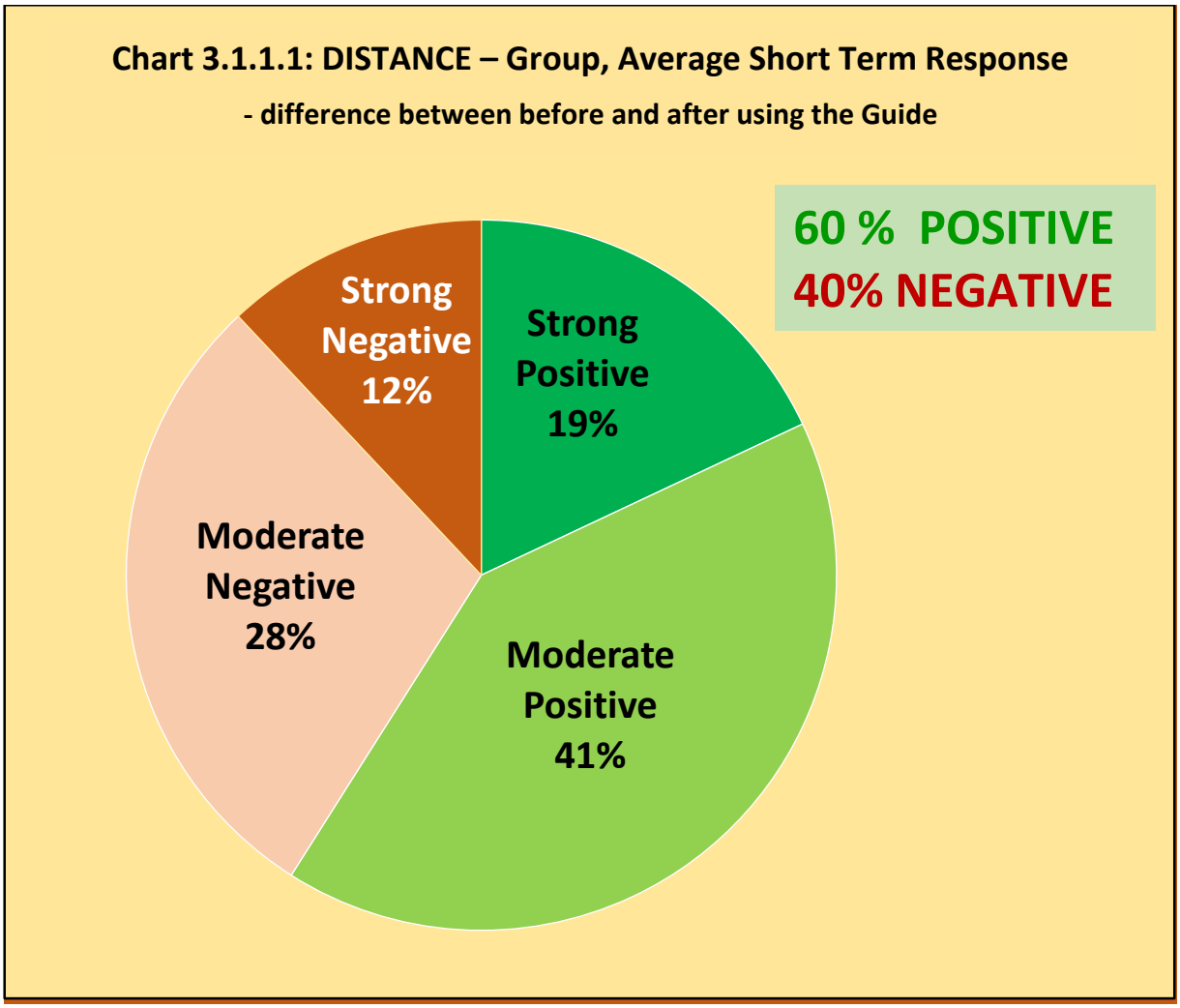
Chart 3.1.1 shows that there was an average, increase in ball carry between pre-guide and post-guide use of 3.90 yds.

Table 3.1.1.1: AVERAGE DISTANCE RESPONSES – difference between Pre & Post-Guide use

DISTANCE	Responders
Strong Positive Responders (Longer Hits)	3
Moderate Positive Responders (Longer Hits)	7
Moderate Negative Responders (Shorter Hits)	5
Strong Negative Responders (Shorter Hits)	2

Table 3.1.1.1 shows the average response pattern to guide use in terms of distance of shot, with a slightly larger number responding positively, post-use, compared to before it was used.

Chart 3.1.1.1, below, illustrates the above response pattern.



In Chart 3.1.1.1, 'Strong' and 'moderate' measures in Table 3.1.1.1 have been grouped together for presentation purposes, to show performance percentages.

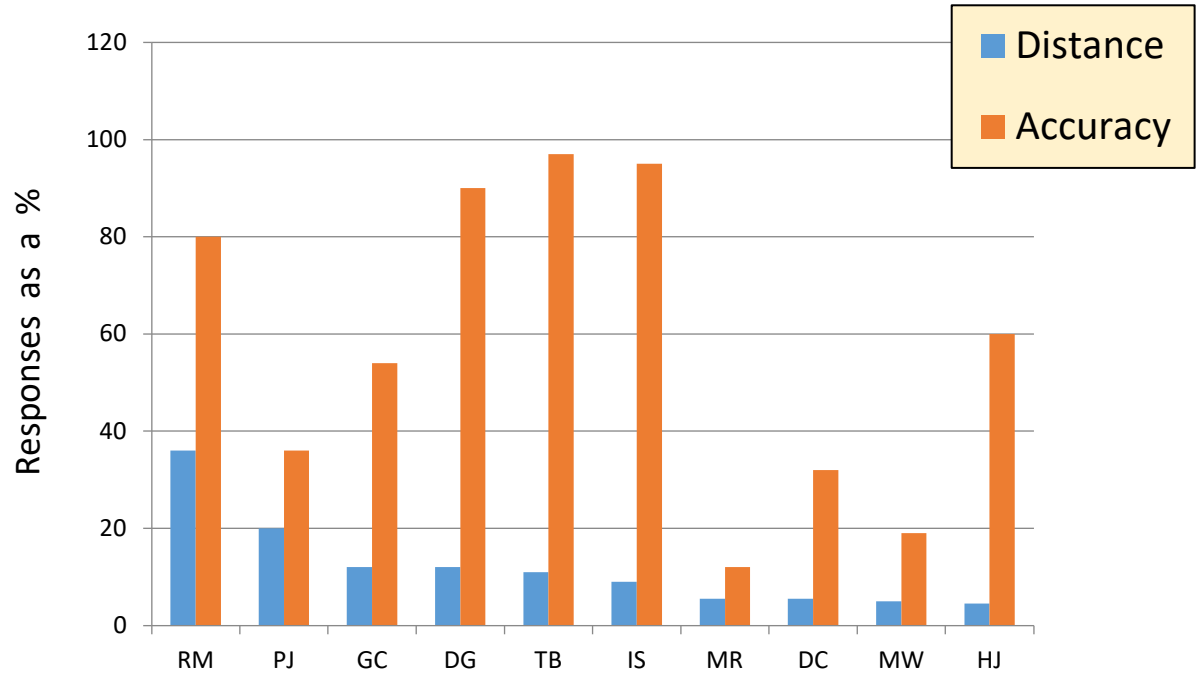
Because the data in Chart 3.1.1.3. displays 'group averages', which included those subjects who did not necessarily show marked performance improvement, it was considered worthy to present the individual average performance, response measures of the top 10 subjects for DISTANCE, and their corresponding average ACCURACY measures, after they had used the guide. These measures are shown in Table 3.1.2, and Graph 3.1.2, below.

TABLE 3.1.2: INDIVIDUAL, short-term performance responses from Guide use, for Distance & Accuracy
(based on top 10, average Distance Response results)

Initials	**DISTANCE – Post use Response** Numbers = Average distance in yards (Improvement as a %)		**ACCURACY – Post use Response** Numbers = Av. distance in yards from target line [0], whether finishing Right(+ve) or Left (-ve)	
	Pre / Post Guide Difference (rounded)	Pre / Post Guide Diff. as %	Difference in distance from target line [Pre/Post Guide]	Difference as %
RM	35	36%	7(R) / -1.4(L)	80%
PJ	19	20%	6.6(R) / - 4.2(L)	36%
GC	15	12%	16.2(R) / 7.4(R)	54%
DG	11	12%	4(R) / 0.4(R)	90%
TB	14	11%	14.7(R) / 0.4(R)	97%
IS	10	9%	0.15 (R) / -3.3(L)	95%
MR	9	5.5%	8.3(R) / 7.3(R)	12%
DC	7	5.5%	2.8 (R) / -1.9(L)	32%
MW	6	5%	0.37(R) / 0.3(R)	19%
HJ	5	4.5%	- 3.5 (L) / -1.4(L)	60%

From Table 3.1.2, the results from the individuals with the top 10 distance scores show a range of distance improvements between 36% to 4.5%, with RM's average improvement being the top result with 35 yards. For the same subjects, the corresponding range of average accuracy differences was 97% to 12%, with TB's, on average being 14.3 yards (closer to the set target line).
Table 3.1.2 figures are depicted in Graph 3.1.2, below.

Graph 3.1.2: INDIVIDUAL, average DISTANCE & ACCURACY RESPONSES
- difference between 'before and after using the Guide', for top 10 Subjects x 'Distance' and associated 'Accuracy' measures.



Of note – all of the top 10 'distance' subjects depicted in Graph 3.1.2 showed greater individual accuracy responses from using the FLAG than their comparative, individual distance responses. Whilst the same

distance-accuracy relationship was found, generally, for the remaining 10 'recreational-golfers in the study, no analyses were made of those relationships.

One could contend that because of the vast difference between golfers' swing patterns [think 'dof'] and even the clubs that they use, it would be time/resource consuming to analyse all the factors involved in why individuals have varying distance and accuracy measure readings - either by analyses of themselves or in comparison to other players/ individuals. When performing on a golf course, the perceived 'best measures' of how the player is going is with his/her distance and accuracy of shots can be measured by one's current 'handicap'.

3.2 F.L.A.G EFFECT ON CLUB DELIVERY and BALL FLIGHT VARIABLES

To investigate how the guide in question affected Club Delivery (CD) and Ball Flight (BF) Factors of the 20 recreational subjects, TrackMan 2 (Performance Studio 3.1) was used. Table 3.2.1 shows how pre-impact variables (club speed and face to path), and post-impact variables (smash factor, ball speed, spin rate, spin axis, carry, height, side and landing angle) were deemed to be affected when the guide was used. Chart 3.2.1A shows another perspective of the same figures.

SIGNIFICANT CLUB DELIVERY & BALL FLIGHT VARIABLES

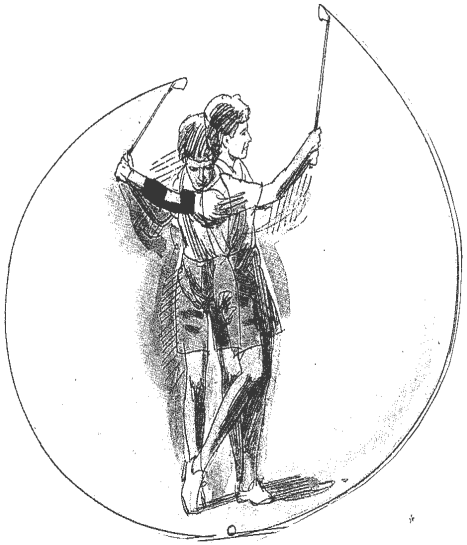
Table 3.2.1 Summary of positive effects from using Guide / FLAG, as per Trackman™ data.

TM VARIABLE (see definitions in Appendix 3)	**Percentage of subjects that displayed a positive response**, when measured as the difference between 'after-guide use' and 'pre-guide use'. **These figures are demonstrated in Chart 3.2.1, below
Club speed	80% increased.
Club face to Path	55% - correlated positively to club path and spin axis.
Smash Factor	60% increased.
Ball speed	70% increased – correlated to club speed.
Spin Rate	75% increased.
Spin Axis	55% closer to 0 (no sideways spin) – with equal numbers in sample recording left/negative or right/positive values.
Carry	72% increased – correlated to ball speed and spin rate.
Side	63% - closer to target line. Correlated to spin axis.
Height	65% had an average ball-flight apex that increased during flight. Correlated to ball speed and spin rate.
Land angle	65% increased. Correlated to spin rate and ball speed.

Chart 3.2.1: F.L.A.G. effect on CLUB DELIVERY and BALL FLIGHT VARIABLES (CD&BF):

Percentage of subjects that displayed a positive improvement (measured as difference between 'after-guide use' and 'pre-guide use').

VARIABLE	% that showed an improvement
CLUB SPEED	80%
CLUB FACE TO PATH	55%



VARIABLE	% that showed an improvement
SMASH FACTOR	60%
BALL SPEED	70%
SPIN RATE	75%
SPIN AXIS	55%
CARRY	70%
SIDE	63%
HEIGHT	65%
LANDING ANGLE	65%

CLUB DELIVERY VARIABLES	IMPACT	BALL FLIGHT VARIABLES

From Table 3.2.1, the F.L.A.G shows as having had a positive effect the on Club Speed of 80% of the subjects, which is correlated to the ensuing improvement in Ball Speed, and Carry, in 70% of the subjects. As well, 55% of subjects showed an improved Club Face to Path, which correlates to improvements in spin axis for 55% of the subjects, and 'side-movement' for 63% of the subjects.

A closer examination of individual results is shown in the following case-studies - A, B, C, D. These subjects, as part of the total group, show similar results were achieved when using the F.L.A.G, but with several variations of note.

3.3 CASE STUDIES – Incorporating Pre-Guide & Post Guide CD & BF Measures of guide effect

CASE STUDY A [Graham C].

Test sequence: Hit shots without guide, (then shots with it on) before more shots with guide off**.**

Difference between before pre-guide use, thence post-guide result is correlated to small increased club speed and ball speeds, and associated, good carry improvement (13 yards).

With accuracy measures for this player, his club face to path moved from (pre-guide) 'open' to club path (initially 2.6^0 without guide on) to, and 3.0^0 'closed'(left) of it, when more shots were hit (post-guide). With associated average spin axis measures slicing/fading less (from 6.5^0 down to 3.3^0), 'side' ball movement lessened from 16.2 yds R (pre-guide) to 7.4 yds R (post-guide).

The positive effect the guide had on average ball 'height' measures (increase of 7.5 yds over initial pre-guide height), is perceived as associated with the average increased spin rate and ball speed that the guide had on these variables.

Likewise, the pre-guide landing angle, compared to post-guide result, shows a 6.9^0 increase.

Graham C TM measures	**Without Guide 1st**	**With guide**	**After guide**	**Comments** - relating to performance when using guide
Club speed	84.1	84.4	84.6	Small increase noted, and possible effect on ball speed, spin rate, and carry.
Club face to Path	2.6	-4.9	-3.0	Result shows 'closing' of club face to path'. Narrowing, negative path (when guide then taken off) is correlated with left 'side' movement and correlated to effect of guide in lessening ball's spin axis/fade.
Smash Factor	1.24	1.23	1.23	Basically, no increase.
Ball speed	103.6	103.9	104.7	Slight increase.
Spin Rate	7224	6531	7774	Increasing effect, once taken off. This can affect time in air/carry, which is what has happened for GC.
Spin Axis	6.5	2.7	3.3	Decreased spin axis, and positive effect once taken off. Means ball is travelling less to right/although still fading, as correlated 'side' measure suggests.
Carry	124.2	134	137.1	Moderate increase in distance.
Side	16.2R	8.4R	7.4R	Overall, flight closer to target line, in conjunction with spin axis being reduced (sideways carry has lessened).
Height	14.3	19	21.8	Increased – and associated with spin rate and ball speed increases.
Land angle	30.5	36.7	40.4	Greater apex of ball flight is noted – means ball may stop on green, quicker, but maybe affects greater distance increase possibilities.

CASE STUDY B [David C].

Test sequence: Hit shots without guide, then shots with it on, then more shots with guide off.

This player's small increase in club speed translated into slightly higher average ball speed and smash factor, alongside a slightly lower spin rate, but which when combined, still gave an average increase in distance (carry) of 15.6 yds further, oncer guide was taken off.

With accuracy, the guide has affected this player's club face to path moved from 3.1^0 (pre- guide) to 2.9^0 left of it (still open to path), when more shots were hit (post-guide). Associated average spin axis measures decreased positively (from 6.2^0 down to 3.2^0), indicating less fade/slice. Accordingly, 'side' ball movement changed from 2.5 yds R (pre-guide) to 1.9 yds L (post-guide), meaning that whilst ball was finished left of target line, it finished, overall, closer to the target line.

For this player, the guide had a positive, correlated effect on average ball 'height' measures of 20.8 yds pre-guide use, compared to 24.3 yds after guide was taken off. Increased 'height' means a potential increase in distance/'carry', which was indicated. Average ball speed increases achieved are associated with the height increase, whilst the lessening spin rate is noted. The increase in 'height' of 'ball flight', above, is associated with the improved landing angle.

See Table of David C's results, below…

David C TM measures	**Without 1st**	**With**	**After**	**Comments** - relating to performance when using guide
Club speed	77.1	77.3	78.4	Guide use correlated with small increases in 'ball speed', 'smash factor' and 'carry'.
Club face to Path	3.1	-0.5	2.9	Guide has had perceived effect of 'closing' club face to path. Closing, positive path is correlated with lessening slice/fade (spin axis) and lessening of average 'side' measure, which for this subject tracked left.
Smash Factor	1.23	1.29	1.27	Small increase once guide off.
Ball speed	94.8	99.6	99.9	Slight increases at each stage – see 'carry' increases, too, which are similarly sequenced, and do increase at each stage.
Spin Rate	6182	4816	5019	Guide had a lowering effect on initial reading, once taken off. Such can affect time in air/carry, which is shown below.
Spin Axis	6.2	3.8	3.2	Indicated positive effect once taken off, meaning ball is slicing/fading less to right.
Carry	134.6	148.1	150.2	Positive effect on distance.
Side	2.5 R	0.7 L	1.9L	Ball flight has finished closer to target line, although left of it. Correlated to lessening spin rate and axis.
Height	20.8	21.0	24.3	Slight Increase – and associated with ball speed increase.
Land angle	39.3	38.3	44.0	Increase correlated to increased ball height.

CASE STUDY C [RossM].

Test sequence: Warm-up; Hit shots with guide on, then shots without it on.

This player's small, average increases in club speed and smash factor have translated into slightly higher average ball speed, alongside a slightly higher spin rate. These when combined, gave an average increase in distance (carry) of 30 yds further once guide was taken off.

With accuracy, the guide has affected this player's average club face to path from 1.4^0 (pre- guide) to 0.0^0 (closely aligned to club path), when more shots were hit (post-guide). Associated average spin axis measures decreased positively (from 9.2^0 down to 0.3^0), indicating less fade/slice. Consequently, 'side' ball movement changed from 5.1 yds R (pre-guide) to 8.9 yds L (post-guide), meaning that whilst ball was finished left of target line, it finished, overall, slightly further from the target line.

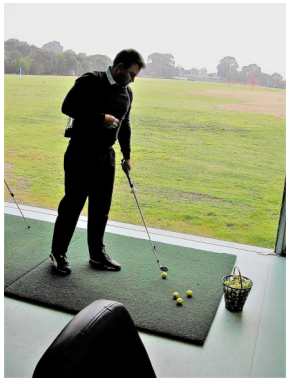
For this player, the guide had a positive, correlated effect on average ball 'height' measures of 11.3 yds pre-guide use, compared to 20.8 yds after guide was taken off. Increased 'height' means a potential increase in distance/'carry', which was indicated. Average ball speed increases achieved are associated with the height increase, whilst the increased spin rate is potentially associated with the increase in distance. The increase in 'height' of 'ball flight', above, is associated with the increased landing angle.

Ross M TM measures	**Warm up - no guide**	**With Guide**	**No Guide**	**Comments** - relating to performance when using guide
Club speed	71.3	70.7	71.4	Small positive effect.
Club face to Path	1.4	-1.1	0.0	Face angle affected – it has changed to be aligned to club path.
Smash Factor	1.21	1.33	1.38	Apparent positive influence.
Ball speed	86.2	93.7	98.4	Positive influence is indicated.
Spin Rate	4532	5310	5426	Positive influence is indicated.
Spin Axis	9.2	0.9	0.3	Clear influence is indicated, and with less slice.
Carry	90.7	117	120.6	Positive (30yds) improvement is indicated..
Side	5.1R	9.5L	8.9L	Average effect on ball flight shows ball has ended up further away from, and left of, target line.
Height	11.3	19.2	20.8	Positive influence is indicated.
Land angle	31.7	39.4	40.6	Positive influence is indicated.

Subject RM 's distance improved after using the guide, but not accuracy, which is not the same result as GC and DC experienced. Was the testing sequence a factor that effected the results?

Results above, and in the remainder of the sample group, indicate that the sequencing of when the guide is used could have a noticeable effect on player performance. Further investigation of the sequence in which the guide is used is perceived as warranted.

CASE STUDY D - Ryan W, PGA Member*



* RW, as a professional, was deemed the "best fit" subject for 3D analyses purposes because of the large range of 'variability' perceived within the golf swings of the other, 20 'non-professional' subjects.

Test sequence: twenty balls without guide, followed by twenty with guide on; 3D and TM measures taken.

For this teaching professional, some improvements in 'swing dynamics' were observed, when comparing swing mechanics and ball flight measures with the FLAG versus without the FLAG.

- Analysis of data captured showed no significant differences in club delivery or shot outcomes/ball flight. However, there was an increased average club head speed to 88.3 mph when using the FLAG compared to 86.9 without, resulting in a 1.5 mph increase in ball speed.

There were several parameters that were significantly different when comparing the data from 3D swing analysis with versus without the FLAG that help explain the increased average club head speed. Of note:

- The time between minimum pelvis rotation and the top of the backswing increased as well as more time with contralateral rotation[1], which resulted in an increased stretch[2] from 11.9 to 14.2 degrees and an increased maximum differential of 43.6 degrees with the FLAG compared to 40.8 degrees without FLAG.

  [1]**contralateral rotation** = *differential (difference)in turn angle between hips (pelvis) and upper body (shoulders) rotation, or* coil at the top of backswing. Also known as ***'X-Factor'*** *(Cheetham, 2011).*

  [2]**stretch** = is the maximum increase in the X-Factor due to the pelvis starting the downswing before the shoulders; also known as ***X-Factor Stretch*** *(Cheetham, 2011).*

- Increases in speed gain - from the upper body to arm and from the arm to the club.

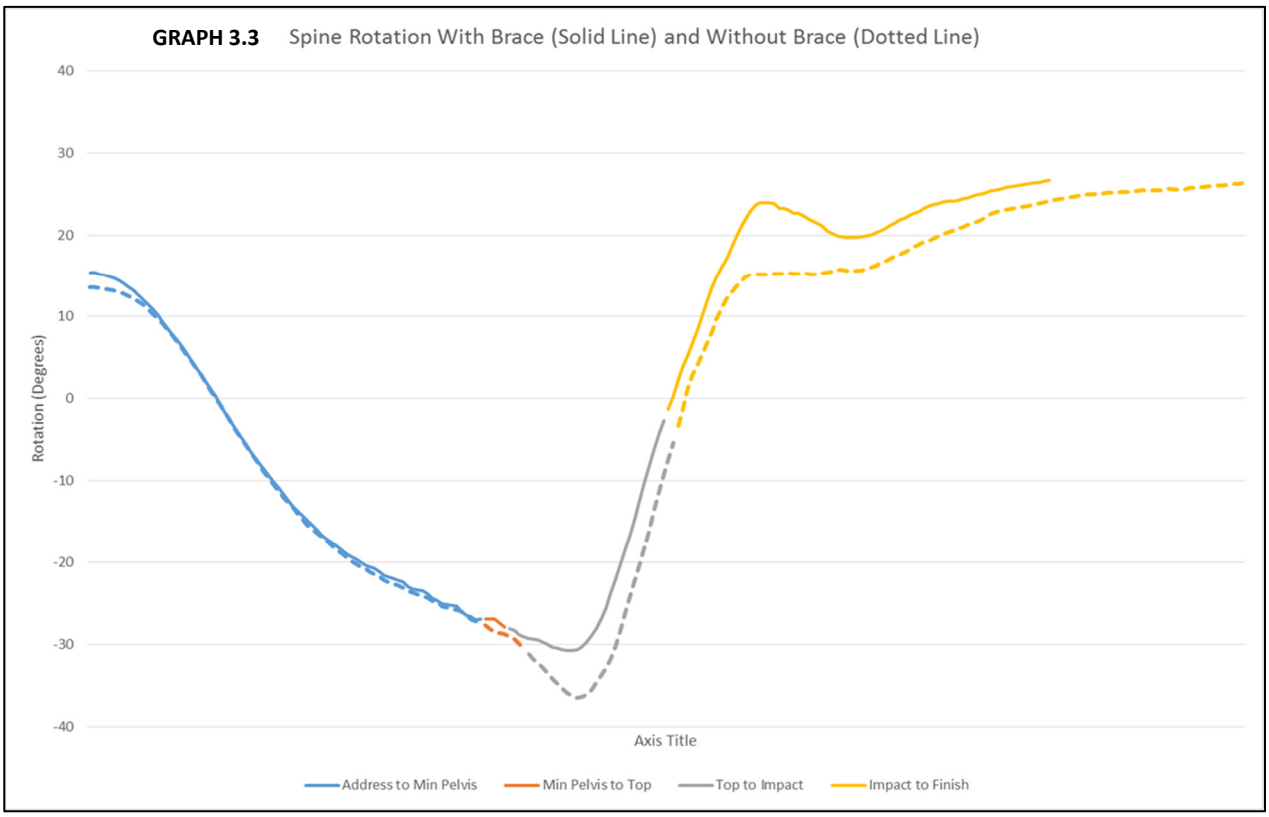
Table 3.3.1 Summary **of RW 's 3D Measures of thorax, pelvis and club-arm**	
1.	Increased peak shaft rotation speed
2.	Increased speed gain from upper body to lead arm, and arm-to-club
3.	Increased follow through time
4.	Reduced spine side bend range
5.	Increased stretch differential (differential between pelvis and upper body rotation)
6.	Increased time from pelvis change of direction to top of back swing (club change direction – leading to 'stretch')
7.	Increased spine rotation range - together with a reduced spine side bend range (#4, above)
8.	less tilting of the pelvis

Ryan W's perception regarding use of the F.L.A.G [when tested 27 August 2015, at Vic Inst of Sport]**:**
"After using the StraightShooter I took it off and hit some more balls. During this 'after use time', without the guide on my lead-arm, for whatever reason, I had greater 'awareness' of where my lead-arm needed to be and how it was working with my chest and back, allowing me to load my backswing more effectively and strike the ball with what I believe was more power and less conscious effort. Like all good training aids, the 'StraightShooter' is amazingly effective, most importantly with the 'feeling' it creates during and after its use".

Graph 3.3 (below), compares RW's spine rotation for representative swings with and without the FLAG, Of note:

- the increased stretch and differential that are evident along with a greater 'rate of stretch' and 'rate of recoil', and which indicate better 'loading' of the trunk' [ie getting ready for the downswing]. This has resulted in a reduced downswing time and the upper body 'closing the gap' more effectively, which aligns to the increased 'speed gain', identified.
- there was also an increased spine rotation range; and
- a reduced spine side bend range with a follow through time that was ~162 ms longer on swings made with the FLAG.

  Here, it could therefore be argued that there is 'less stress' being placed upon this individual's body during the swing.



As for the previous three Case Studies, measures of RW's CD&BF variables were made using TrackMan, and results are shown in Table 3.3.2.

Table 3.3.2 Next page.

Table 3.3.2 Effect of guide on Club Delivery & Ball Flight variables, for subject RW.

TrackMan™ Measure (see definitions in Appendix 3)	Effect of guide (average RW measures)
CLUB DELIVERY Club head speed	increased: 86.9mph, without guide versus 88.3 mph, with guide
Club Face to Path	increased: - 0.8 to -1.6 (further Left)
BALL FLIGHT smash factor	similar: 1.36 without versus 1.35 with guide
ball speed	increased: from 117.9 without to 119.4 mph with
spin rate	slowed: 5271 rpm to 5069 rpm
spin axis	similar: - 0.9 degrees without versus - 0.9 degrees with guide
carry	increased: 162 yds without versus 165.4 yds with
side	increased: 3.7yds L without versus 6.0 L with
height	similar: 24 yds without, versus 24yds with
land angle	similar: 40.5 degrees without to 40.3degrees with guide.

From Table 3.2.2: RW's Increased Club Speed appears to have translated into increased ball speed, which correlates to greater carry/distance from use of the guide. Correspondingly, his accuracy when using the guide is perceived as 'decreased', shown by slight changes in Club Face and corresponding Spin Axis measures.

4. CONCLUSIONS

This preliminary study was established to test the hypothesis that the nominated Flexible Lead-Arm Guide (F.L.A.G.) would have a positive effect on a golfer's immediate and short-term performances. General comments are made about the study and its findings, before more specific comments are then presented:

GENERAL

- Amongst the plethora of golf coaching devices and aids, plus recommended ways to improve one's game that can be found in the golf-market, no data was found on this type of flexible, lead-arm-guidance device (FLAG) that, allows the user's lead-arm to 'fold' during their follow-through.
- Augmented feedback (eg praise, or using a physical guidance device) is a common component of the communication between instructor and student in skill learning. Physical guidance devices can assist some people, but not all people.
- This preliminary study has highlighted the variability that exists amongst a group of right-handed, Australian, male golfers', average accuracy and distance measures when using their favoured 7-iron, and in conjunction with the nominated F.L.A.G. Whether the results of left-handed golfers and females of varying ages not included in this study, would be similar to those found for the right-handed males in this study, could be worthy of further testing.
- Despite its preliminary nature, this study has sought to give players and coaches a more quantitative account of what can be achieved by guiding the lead-arm of participants tested and could offer a direction for future investigation into arm-guidance devices.

Summary of averaged data

- No significant differences were found between group mean results for participants operating with, or without the guide. There were some trends for higher launch angles and greater accuracy, but these were not statistically significant.

SUMMARY OF SPECIFIC RESULTS [N.B: Comments apply to right handed golfers].

SHORT-TERM, POST GUIDE USE

(a) Associated short-term performance dynamics:

When average measurements were taken immediately after the guide was used, and compared to before it was used...

For Distance: 60% showed a positive performance response to using the guide, with the average increase in distance being 3.90 yds, and the best result being an average 35 yards of improvement.

For Accuracy: 83% of the group showed a positive response to using the guide with the average increase in accuracy being 2.50 yds, and the best result being an average of 14.3 yards improvement [closer to the set target line].

When looking more closely at the averaged, short-term performance responses of the top 10 subjects for *distance*, improvement-correlated-to-guide-use ranged between 4.5% and 36%. Correspondingly, for individual *accuracy* improvement, the same top 10 *distance* subjects had positive *accuracy* improvement responses which ranged between 12% and 97%.

As the study method did not give specific directions to subjects regarding what to focus on during their testing (either 'accuracy' or 'distance'), any negative, distance sub-set of subjects' results could have occurred because those subjects made their own decision to forgo 'distance' for 'accuracy', or vice-versa. More research on this aspect of the results may be warranted.

However, as the involvement of several correlated club delivery and ball flight variables were inferred in the results for the above distance and accuracy measures, an investigation of these variables was deemed warranted, and are shown fully in Section 3.3 of the Report, with a summary below.

CLUB DELIVERY & BALL FLIGHT VARIABLES

(a) Club Delivery

Whilst there were some small differences in average values for performance responses to club delivery variables, there does not appear to be a pattern of club delivery learning responses following short-term practice with the guide, with approximately the same number of positive and negative responders in all club delivery parameters.

However, when analysing the individual results for club-delivery after using the guide, the following average, positive responses were shown:

- Club Speed 80% of the sample had a positive response, and
- Club Face to Path 55% of the sample had a positive response.

(b) Ball Flight

Some group, average launch parameters were slightly different between guide and no guide conditions. Spin rates and spin axis showed some small differences, whilst pre-and post-guide conditions show that there are some potential differences in average launch variables, particularly in spin rate (according to the average z scores).

But when analysing the individual results for ball flight, after using the guide, the following per-centages of the sample group, showed positive responses, based on their average scores:

- Smash Factor 60%
- Ball Speed 70%
- Spin Rate 75%
- Spin Axis 55%
- Carry 72%
- Side 63%
- Height 65%, and
- Land Angle 55%

3D ANAYLYSIS of PGA Member - RW

When RW's actions were examined, the greatest response to the guide appears to be found in variables related to posture such as spine maximum and minimum angles as well as range of motion. Specifically, the following factors showed increased/positive readings:

- Peak Shaft rotation speed.
- Speed gain transferring body to club – indicating better 'summation of forces'.
- Follow-through time meaning more time to dissipate energy/less chance of injury.
- Increased 'stretch differential' between pelvis and upper body rotations.
- Relating to previous, also – increased time for pelvis to change direction at top of backswing (meaning, potentially, an increased 'stretch' at the top of the 'take-away');
- Increased spine rotation range.
- less tilting of the pelvis, meaning less 'stress'; and
- Increased – club head speed, and ball speed – meaning an increased distance.

In this study, circumstances did not allow for the measurement of the effect that the guide may have had, over a period greater than immediate, post-use. Consequently, it was perceived that it could be beneficial to assess any such effect after 1 week, 4 weeks, 3 months, etc, to see if any changes occur in the performances of the subjects, compared to those noted in this study. Neither was the best sequence of use of the guide investigated, and as such, is therefore also considered worthy of further investigation.

Anecdotal Evidence

Some anecdotal evidence (Appendix 2) does show positive effects over longer periods than immediate, post-use. Such anecdotal feedback related to subjects commenting on their improved confidence after using the device, an increased, on-going awareness of where the lead-arm is and should be, and an opportunity to focus less on the lead-arm and more on other important swing-pattern components. Some of the evidence offered anecdotally but which was outside of the study design, further indicates that the FLAG provided longer, on-going benefits than the results identified by this limited, preliminary study.

More research on the extended-time usage of the guide and its effects that surfaced after the study appears warranted.

CONCLUDING REMARKS

The effective use of physical guidance feedback appears to depend partly on understanding the various effects of this feedback on skill learning and the conditions that characterise the occurrence of each effect. Of the distinct relationships between augmented feedback and skill learning that have been previously identified (Magill, 2012), some appear to have been evident within this study:

- augmented/physical guidance feedback is necessary for learning some skills – potentially expressed by those who have had a positive response to the FLAG. However, since this study did not follow the subjects who were at the lower end of positive response to the FLAG, for an extended period, it could be that they too may achieve improved 'test results' had they had use of the guide over a extended exposure time.
- augmented feedback/physical guidance is not needed to learn some skills. This is possibly expressed by those who have had a neutral or negative response to the device in this study.
- for some skills, augmented/physical guidance feedback enables the learner to acquire the skill faster and so achieve a higher level of performance than would be possible without it. Here, this is very likely expressed by those in the study who have had a higher-level response, as compared to those who had a lower level response, or those who had no response at all during the study;
- augmented /physical guidance feedback can be provided in such a way that it hinders skill learning. No indication of such hindrance was recognisable in this study, but cannot be completely ruled out.
- Based on the results from this study, further investigation of the preferred learning sequence in which such a physical guide is used, is warranted.

This study has not answered all the above issues and questions, nor was it designed to. However, the investigation and its measurement parameters has potentially opened several avenues for future research into this avenue of golf swing education through physical guidance feedback. The results from this study could warrant and encourage further investigation into this field.

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6. APPENDICES

APPENDIX 1: Supplementary Data Analysis information

Average values for all variables and subjects were collated to determine the overall average value for each variable both with and without the guide. The difference between the guided and unguided overall averages was then converted to a z-score (the difference between the averages was divided by the standard deviation of the without guide condition).

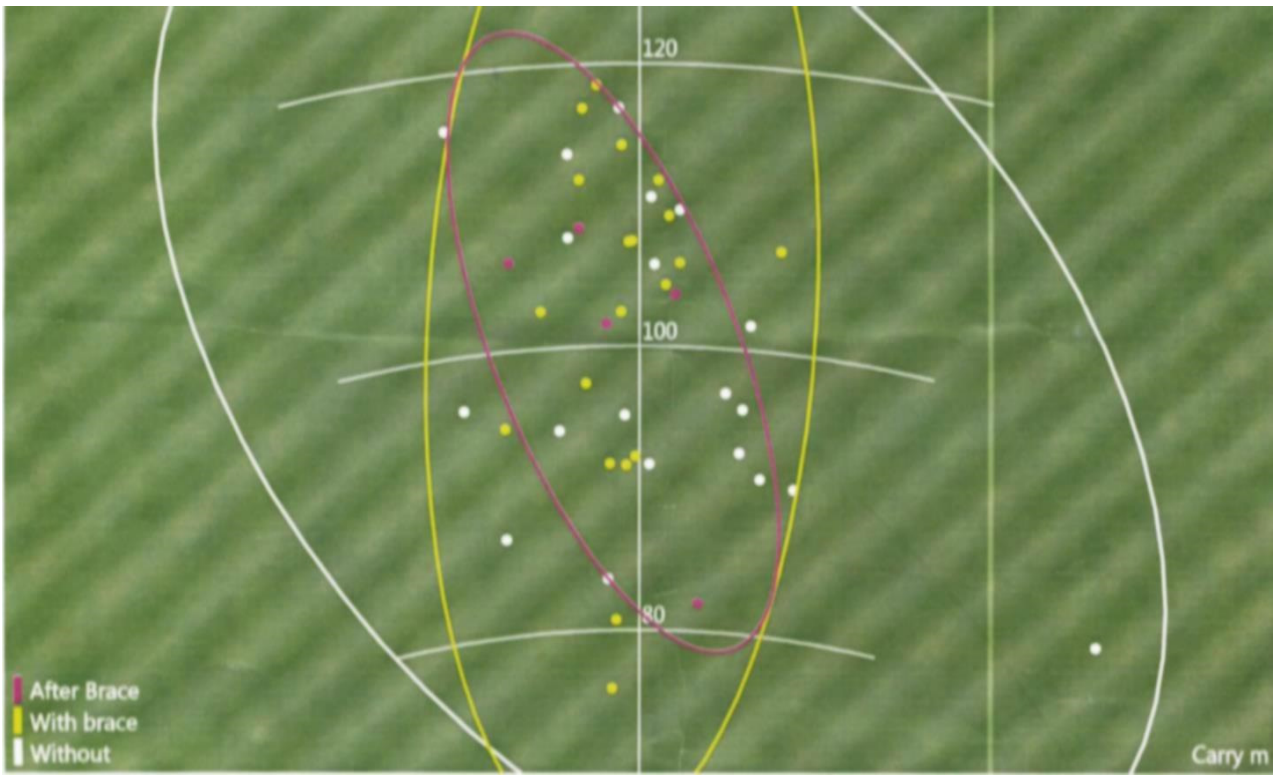
To determine the response of individual subjects, the individual z-scores were also collated. These are the within subject differences between with guide and without guide conditions expressed as standard deviations of the without guide condition.

Performance responders were identified by calculating the z-score of the post-guide results to the pre-guide results (z-score = [post-guide average – pre-guide average]/pre-guide z score). A z score of over 0.5 was classed as a moderate responder. A z-score of over 1 was classed as a strong responder.

APPENDIX 2: ANECDOTAL EVIDENCE – Test Subjects, 2015

AE – Subject 1: MW – tested Weds 7th October 2015

Testimonial – "Hi, My name is Mal Williams. I am a member at Wentworth Golf Club, Orange, am 65 yrs young, and a 13 marker. I was asked to try out the 'Straightshooter' in a practice session on 7th October, 2015, using my trusty 7-Iron. The following weekend (Sat 10th October 2015) I was amazed that playing in a comp. round, that I finished 3 under my handicap. The biggest change in my game is that I am focusing on a 'straight arm takeaway', and my ball striking is so much better".



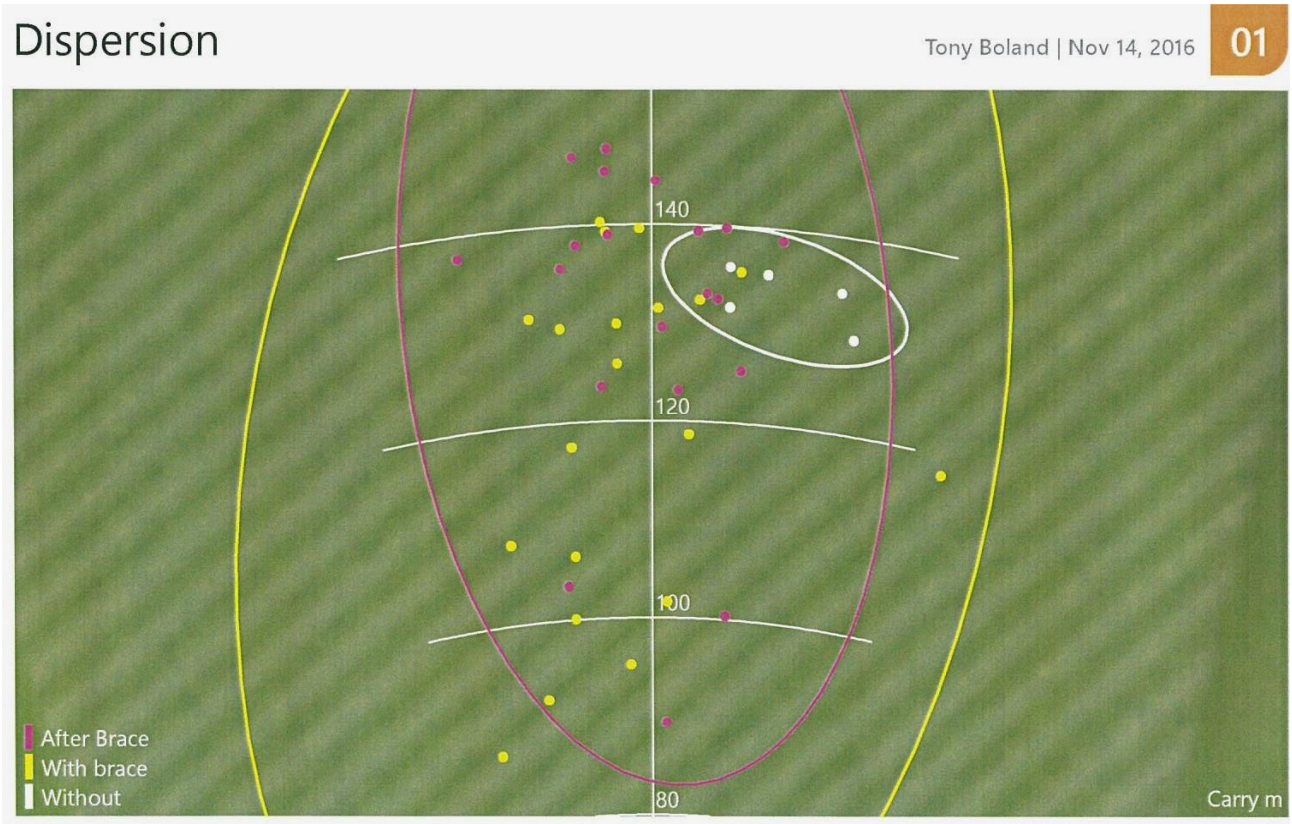
TEST ORDER – showing TRACKMAN™ results:

1st Test: WITHOUT GUIDE-WHITE
2nd Test: WITH GUIDE -YELLOW
3rd Test: WITHOUT GUIDE - MAROON

AE – Subject 2: Tony B Subject tested Weds 14th October 2015

Testimonial - **"**When tested using the 'straightshooter' in October 2015 my GA [Golf Australia] handicap was 22.6. By February 2016 it had dropped to 18.1. The difference after using the 'StraightShooter' is that I have consciously become aware that if my lead-arm is not straight or close to straight, and this has been a strong contributor to any poor result that occurs in my shot-making. This mental attention then helps me re-focus on that part of my swing. And only for my putting, I would probably have an even better handicap than at present" (25 March 2016).
"My golf improved significantly enough to be made captain of the Division 4 Pennants team for my local club in February 2016 and we went through to the final. I would never have achieved this without the use of the Straight Shooter".
[Tony B /C-Grade , Club Member]

May 2016…. TB won Wentworth GC Monthly Medal with a net 65.



TEST ORDER – showing TRACKMAN™ results:

1st: White: Without/practice – 5 balls;

2nd: Yellow: With guide – 20 balls;

3rd: Mauve: After guide – 20 balls.

AE – Subject Colin M – June, 2015

"When I heard about Straightshooter, I was happy to try it, on the chance it could help sort out some of the problems I had been having with my game. Always conscious of needing to get a good start on the 1st tee, not being so nervous, and prepared to have a look at anything that could improve my consistency, the Straightshooter has measured up exceptionally well in my mind.

To trial the device, the Straightshooter Inventor and I played 9 holes together.

I played the first two holes without it on, and I was straight into to my old-tricks… wayward, feeling a bit down because of how my game was going, etc. Things changed when I fitted the device. It immediately gave me an improved 'feel' for where my lead-arm should be, and by the time we had reached the 9th green my confidence was running high – with shots now constantly finding the fairways. I immediately wanted to know when I could purchase a Straightshooter.

What the device offers for me is greater confidence, less nerves, the chance to learn how to get a better start to my round, and thus more consistency". [*ColinM / RHander / C-Grade Club Member*].

AE – Subject Ryan L – Dec 2016

"Having analysed thousands of swings for golfers of all standards over the past 15 years, one of the most important aspects of any swing to me is how the arms connect or 'match' with the body during the movement.
Often the source of 'swing issues' relates to how the lead arm connects to the trunk, which result in compensatory movements that compromise 'swing dynamics' and how effectively the club is delivered to the ball. Examples would include:

- The lead arm moving across the body during take away causing the upper body to tilt, affecting rotation and 'loading' into the right-hand side during the backswing.
- The lead arm 'locking' during take away affecting wrist mechanics and how scapular muscles can work to stabilise the shoulder girdle and arm
- The lead arm 'locking' (increased tension together with elbow extension) in transition, affecting how the 'set' of the club can be maintained and how the club is 'released' into impact
- The lead arm 'pulling' down in transition causing elbow bending during the downswing and often resulting in the arm 'winging' post impact
- Tension in the lead arm at set up together with the upper arm 'pinned' to the rib cage compromising 'spine angles' and how scapular muscles can 'activate' to stabilise the shoulder girdle during subsequent movement

The F.L.A.G I feel is a training aid that together with some direction on its use and correct swing concepts can assist with some of the above issues. Due to its design, it helps with arm tension which is important for both shoulder and wrist mechanics. Also due to the design, the arm is able to 'fold' appropriately in follow through - it would be a concern if a device was making the lead arm 'rigid' during this phase of the swing.

Having done some testing with the FLAG for a player using 3D analysis and trackman to compare swing movements and ball flight outcomes, we have seen some positive results in terms of the influence it had on 'swing dynamics' and club delivery (see case study D) when using the FLAG.

While the response would be expected to be different across different individuals, using such a training aid during practice can help give players more awareness for better movement and an understanding of what this 'feels' like to them. How well an individual 'internalises' these 'feels' will dictate how well they can recreate and reinforce them following practice with the FLAG, but there is potential to help accelerate the improvement of a number of 'swing issues' through the correct process of practice with the FLAG".

[*Ryan Lumsden / Golf Biomechanist / Q Golf, Australia*]

Ryan Lumsden (left)
Golf Biomechanist
Q Golf, Australia
- with client

Other Testimonials can be found on 'Simplified Sports' Website.

APPENDIX 3 TrackMan™ definitions for variables measured in this study.

TM Variable	Definition
Club speed (mph)	Club speed measured just before impact
Club face to Path (degrees)	Club head angle calculated at impact on the club face relative to Club Path.
Smash Factor	Ball speed divided by Club Speed – ie ability to transfer power from club to ball
Ball speed (mph)	Measured just after impact
Spin Rate (rpm)	Launch spin measured just after impact
Spin Axis (degrees)	The axis around which the ball is spinning. The tilting of the axis dictates if the ball will draw or fade. Positive value when ball is going right – and negative when it is going left.
Carry (yards)	Distance from impact to point where ball lands (flat).
Side (yards)	Carry measured in relation to target line
Height (yards)	Measured height (apex) of the ball during flight.
Land angle (degrees)	Angle ball is landing relative to horizon.

About ***Simplified Sports Pty Ltd (SSPL), Orange, NSW, Australia***

SSPL was set-up in 2007 to formalise Research & Development activities associated with sporting activities identified as possibly needing improvement, by SSPL's Managing Director, Michael Middleton.

Middleton has qualifications in Human Movement/Biomechanics, Education, Psychology and Ergonomics with over 40 years' experience in applied sports coaching, education, and workplace design and improvement. Here, thinking has also been that playing golf is 'work' for professional golfers.

By utilizing a 'creative approach' to studying selected sports activities, Middleton has designed and implemented several coaching devices. These have reduced the learning time required for skills acquisition and enabled the learner to improve the performance and enjoyment of their sporting activity.

Specialist support personnel have been engaged, over time (eg Engineer and co-designer, Dave Farrell) to help refine the design and application of training aids – so far for cricket and golf.
Other devices and applications are already in mind for future development.

***SSPL: "Better performance = greater enjoyment"**