The effects of face angle biofeedback on performance in a golf putting task.

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Abstract

This study investigates the effectiveness of technology in improving success and accuracy in golf putting, with a focus on instant feedback regarding the face angle at impact. Differences in perfection and imperfection are tiny and not always obvious to the human eye. Using the Quintic ball roll system gives an insight into what exactly is happening throughout the swing and most importantly, for this study, how that is affecting the face angle at impact. 20 experienced golfers (10 using technology, 10 not) took 25 putts from 12 feet with the goal of putting as many as possible into the cup. The 10 using technology were able to review their putt and the data using Quintic which allowed them to adjust their next or future putts. The end position of each putt in relation to the cup was measured to show overall accuracy.

The aim of this research was to assess if immediate feedback would lead to more accurate and successful putts. Results indicated that the Quintic group had more made putts but also had a further average distance from the hole in total. However, the final 5 shots showed a significant improvement; more putts were made and a closer average finishing difference was achieved. This suggested the adjustments that were made due to feedback allowed for greater success in the latter parts of the testing.

The study does acknowledge limitations, including the need for further exploration into the long-term effects of using technology within a player's training schedule. Overall, this research shows the potential offered by technology to improve a player's putting performance and how the integration of technologies to enhance putting skills may pave the way into a new thinking and clarity about how to train this skill.

Key words	Quintic Ball Roll	Biofeedback	Golf Putting	Face Angle	Golf Technology

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Introduction

Background

When playing golf, the player's aim is to take the least number of shots during the round in order to get the lowest score. Pelz (2000) found that 43% of those shots were taken when putting, showing that putting is a crucial element in shooting the best possible scores. Putting is a term used for the type of swing and club, called a putter, used when close to the hole on the green. It is a delicate shot that requires very little power meaning the swing is short and there is no bend in the arms during the backswing phase. Putting is considered to be the simplest shot to perform and yet many amateurs and professionals struggle or their performance is inconsistent without a clear understanding of how to improve or correct their technique. Alexander (2005) suggests, the age old adage of 'drive for show putt for dough' is still the case. The Professional Golf Association (PGA) has an average putt percentage of just 22% from 10-14 feet and a 20-handicap golfer has an 18% success rate from this distance (Hall, 2024). This shows around only 1 in 5 putts from this distance go in, which strongly suggests this is an area of the game where there is a significant opportunity to gain strokes (reducing the number of shots taken to complete the hole and the round). Therefore, testing was conducted at 12 feet to ensure it was a challenging distance and allow for potential differences to be made apparent from testing results. Also, it is a part of the game where vast improvements can be made, so research into it is relevant and useful.

The skill of putting

The skill of putting in golf can be broken down into phases. These include the backswing, contact phase and follow through. For this research the contact phase is being focused on. However, any discrepancies during any phase of the shot may have an impact on the end result. Delay et al (1997) notes that muscle force must stay constant for each shot and any increase or decrease will have a resultant effect on the velocity of the shot. This strike of the putt needs to have a good tempo, ensuring the swing is smooth throughout. This means the time from impact to the ball's 'true roll' (Koslow, 1998) is shorter, simply meaning the ball will roll instead of bounce, which may take it offline. Also, when striking the ball, the middle of the club face needs to strike the middle of the ball. Any slight offset will result in unwanted spin, resulting in the ball going offline. These factors aren't being assessed in this research, but it is important to note as it could cause changes that aren't expected especially if face angle at contact appears to be good. Farnsworth (2009), who is regarded as the "putting doctor", highlights the importance of the entire technique when putting. This includes breaking the whole skill down into: the setup, mechanics, distance control, alignment, green reading and mental aspects. Golfers will all have different techniques when taking a putt, mainly described as either arm putting or body putting (McLaughlin, 2013). However, the desired outcome is the same with achieving perfect face angle, ball speed and aim point. Players also face other factors such as green reading, aim, stroke and ball roll (Karlsen et al, 2008). Crews and Lutz (2008) found in their study that in 80% of putts taken the golfer perceived the hole to be either left or right of its actual location. Kenyon (2008) also highlights the importance of the ability to read the green and create a conscious target to be able to account for the slopes of the green. Golf requires both brilliant hand eye coordination skills, as well as a solid mind set and mental resilience. Kirschenbaum et al (1998) study showed those with a strong mental strategy would be able to decrease scores. This strategy was a simple 3 step shot; Plan, Apply, React (PAR). This can remind a player to play shots

that are constructive rather than destructive. This is important when putting because sometimes with a long-distance putt, a player will choose to get the ball close to the hole so that they are confident that only one further shot will be needed to make the putt, rather than the more risky approach of trying to hole the ball, when there is a much greater chance of error resulting in more than one additional shot being required to make the putt. Kirschenbaum et al (1998) refer to this strategy as a lag putt. rather aim to get the ball close, known as a lag putt. Getting the ball within a close radius to ensure only one other shot will be taken instead of trying to get the ball in the hole and risking it going wrong, potentially costing another shot.

How to train putting

Training is fundamental to becoming better or staying at the top of your game. Guadagnoli and Bertram (2014) stated golf isn't how well you play but instead how well you practice. Having a perfect technique is critical in feeling confident about each putt. Hodge (1968) stated that this confidence will only be achieved once the mechanics have been mastered. A player's ability to putt accurately and consistently under pressure is key. Being able to train so that the golfer is more accustomed to the feeling when it is happening for real is vital. Kinematics mechanics and coordination decrease when under stress or anxiety (Tanaka, 2010). Gray's (2013) study found top performing putters are able to control the speed and distance when putting under pressure, suggesting that players who 'choke' (Baumeister and Showers, 1986) under pressure weren't hitting the ball hard enough due to the fear of hitting it too far. This resulted in less than optimal mechanics, leading to differing and poorer outcomes. Training aids are tools that help to easily feel the correct technique, such as a glove that has markers on it to show grip positioning (Carson, 2019). Many players will use other physical training aids such as alignment sticks, laser assistance, putting mats and putting mirrors. These all give instantaneous feedback and help in perfecting technique as well as highlighting issues and potential faults within the motion. Coaches are turning to tools that physically restrain (Busuttil et al, 2010), which ensures the perfect technique is being constantly practiced in the hope it will transfer when the aids aren't being used, because the player is used to exactly how the movement should feel each time. Mental training is key for a player to remain calm and confident for each shot. Pre shot routines are used by all golfers and are essential in focusing the mind. Crampton (1989:10) stated that 'elite golfers appear to do the same things in the same order and with the same timings.' It has been shown the pre shot routine increases behavioural consistencies when performing the task (Cotterill, 2003). When training, players should follow their own personal routine each time as that is what they would do when playing. A pre shot routine usually consists of alignment of the ball and where you want to hit it and visualisation of the shot you are about to perform and practice swings to gauge the club speed required. Each routine is specific to each golfer - some will be fast whereas other may take a lot longer. Coaches will set up practice drills to work on either accuracy, speed or a combination. Usually, these drills will be short with different adaptations possible to ensure the task doesn't become boring and players lose interest or concentration. Fisher and Fairbrother (2019) suggested practicing drills blind will allow for more sensory feel. Being able to change the type of drill will work on body physiology of the shot as well as the psychological processes during each shot.

Technology within golf

Golf like many other sports now heavily relies on technology to find advantages as well as allowing the simulation of real life activity from anywhere. This technology includes simulators, ball and eye trackers, force plates and slow-motion, high-definition videos (Pauls, 2017). Also, technological advancements are made within the clubs, balls, tees and clothing. Most modern golf facilities will have a magnitude of these technologies to assist in coaching and individual learning. These technologies are used to give information regarding the outcome of a movement in the acquisition and development of the skill (Adams, 1971). Biofeedback uses technological monitoring equipment to give instantaneous information of physiological processes (Schwartz and Andrasik, 2017). EEG-neurofeedback is becoming an appealing technique which gives real time feedback from the cerebral cortex and can improve cognitive and sports performance (Wu et al, 2023). One of the most common and researched technologies for putting is the use of eye trackers regarding the quiet eye. The quiet eye (QE) is defined as the final fixation on a location for longer than 100ms (meters per second), within 3 degrees of visual angle (Vickers, 2007). Vickers (2012) found the golfers with a longer QE duration were able to maintain focus, leading to better putting results. Walter-Symons et al (2017) found that lower handicap golfers had longer QE durations. Instant biofeedback allows for improvements to be made that a golfer can consciously attempt to improve immediately. These different technologies all focus on certain aspects of the skill. Elite golfers are also now sponsored by companies attempting to push their technology out into the market. Very little data exists into whether this technology is improving the players or not. However, many fans who idolise these top players will want to use this technology and training methods if they believe the players do. Chung (2013) found Nike made an additional 103 million dollars by selling the golf ball that Tiger Woods was using. Whether this ball was any better than any other is highly debated. Regardless, many golf players chose to use this ball given that Tiger Woods was the best player in the world at the time.

Limitations

This study did have limitations. One of these was the number of participants. The guidelines set out to make sure this was a reputable piece of research meant there were limited participants who fitted into the criteria. In future making guidelines less strict or finding a larger population to ask may increase the number of participants allowing for more data, which will give a more accurate representation of the results. This study was conducted indoors. This was due to the Quintic system requiring electricity to run. The indoor carpet has a different speed which participants had to adjust too. Collecting data and practicing outdoors is important as it allows for whole skill acquisition even while focusing on certain aspects of the shot. It would be more realistic as golf is a sport that is played outdoors.

Quintic Ball roll System

For this research the Quintic ball roll system was used. This system captures 720 frames per second. It gives instant data on; club head path and speed, club face angle at contact, club face rotation on follow through, ball spin and ball speed. All this data is also able to be stored for use in the future. This technology is ideal to assess if face angle is the root cause of a poor shot. Also, as it tracks the putter head throughout the shot, more specific changes can be made in relation to where a potential issue may have occurred, allowing for more specific adjustments to be made. There was limitations to the Quintic technology as it required an

electricity source and a certain light level to calibrate. This limits where you can carry out training with it.

Why we carried out this study

The rationale for this research is 2-fold: If a golfer wants to train with the intention of improving their putting, there is very little data and information about the best ways to do this. There is a lack of research data relating to the effectiveness of technology in improving putting performance or making it worse. Considering it is such an important aspect of each round of golf played finding a tool which offers an edge to training and becoming a better putter would be highly beneficial in order to shoot better scores and hopefully win tournaments, whether that is for club players or elite players on the professional tours.

Aims and hypothesis

Therefore, the aim of this study is to assess whether to use of technology is a beneficial training aid to increase the number of putts a player is able to successfully get in the cup as well as improving overall accuracy relating to the distance the ball finishes from the hole. We hypothesised that the participants using technology would have a better overall accuracy with more successful putts, and also that when the putt was not successfully made, the average distance from the hole would decrease with every 5 putts.

Methods

Participants

20 experienced, right-handed golfers were tested. They were randomly split into 2 groups, 1 control and 1 using the Quintic ball roll system for immediate feedback. All participants were members of Manchester Metropolitan University's golf team, aged 18-23 and with a handicap of between 3-20. Ethical approval was granted by the Ethics Board at Manchester Metropolitan University. All participants were volunteers. Ethical considerations were abided by throughout. A health and safety risk assessment was carried out before testing to ensure participant safety. This research however did not include many risks as it was a non-invasive study. Ensuring there was adequate space to perform the study was the main concern. This allowed for participants and researchers to have enough operating space, therefore reducing any risk of injury. All participants were anonymous and were given participant numbers.

Apparatus

The technology used in this research was the Quintic Ball Roll System (figure 1). This consists of an LED bar light and a camera system which captures 1080 frames per second (Fps). In turn this gives feedback on: face angle, ball spin, ball speed, angle of attack and clubhead loft. In the form of a replay video of the shot and picture graphics to explain each factor.

The same putter (Dunlop blade putter) and same ball with 3 black dots (Titleist pro V1) were used throughout as they were calibrated to the Quintic system. Meaning players couldn't use their personal clubs. Figure 2 shows the calibration process.

The 2m by 2.5m target area was set out using tape measures. A cup was placed at 1m by 1m and was the centre point from which the co-ordinates were taken. Figure 2 shows the layout of the putting mat. Ensuring the Quintic system was properly set up and calibrated was crucial to maintain validity throughout the testing. To set up the system a laser line was used to ensure the ball was on a perfectly straight line to the hole. The ball was then placed with the 3 black dots facing the lens, with the camera 127cm from the position of the ball. The LED bar light had to give a ball brightness of 90-120 Lux with there being no more than 10 Lux between the 2 readings. Lastly a ball calibration test was run on the laptop (Figure 3). The club was then calibrated. This was done by using 2 dots on the bottom of the shaft and on the toe of the putter (figure 4). A measurement from the toe to the middle of the club face was then calculated, to know the middle point of the putter face (figure 5). The putter head was put in the stance position behind the ball, the calibration test was the run. A scorecard (figure 6) and graphs were created for each participant to show the finish position of each shot (figure 7).

Procedure

Each participant took 25 shots with no warm up strokes. Each shot was taken from 12 feet. This distance was decided as previous research data collection from this specific distance is low and offers the most valuable data possible. This study uses a distance of 12 feet because there is very little research currently available for this distance and so this will make a valuable contribution to the wider study of the use of technology to improve putting performance.

The co-ordinates of each shot were recorded based on its end position regarding if it was in front or behind the cup, as well as if it was left or right. The participants using the Quintic technology were able to read the data from each shot instantly (figure 8). This included the ball speed, face angle and rotation through the shot. This encouraged changes to be made from each shot, if required. The participants were advised to carry out their own personal pre-shot routine and no time limit was set between shots. Participants were not permitted to have any pre-existing knowledge of the set up or putting surface. Each subject was calendared separately to undertake the research to ensure there was no bias from subjects communicating with each other beforehand or having varying levels of knowledge of the setup prior to their participation in the study.

Validity and reliability

When designing this research, it was made with the simplest set up possible. This is because making it repeatable was a key target as data and research on this topic is low. Other studies in this area have been broader which may not give a clear reason as to why an outcome occurred. For this research we wanted to try and create an understanding on something that hasn't been researched much and is currently used depending on preference rather than because of any objective research which supports its usefulness in improving performance. and not if it is the best way. This data set is reliable as each participant fulfilled the required

skillset specified on the participant information sheet and all filled out consent forms before testing took place.

Microsoft Excel was used to collate data with the statistical calculation of the mean and standard deviations carried out using this software. SPSS was used to run independent sample t-tests and paired t-tests. These were used to show any significant changes within and between the 2 groups. Line graphs and scatter graphs were created for every participant to visually show where each putt finished.

Figure 1: The Quintic ball roll system.

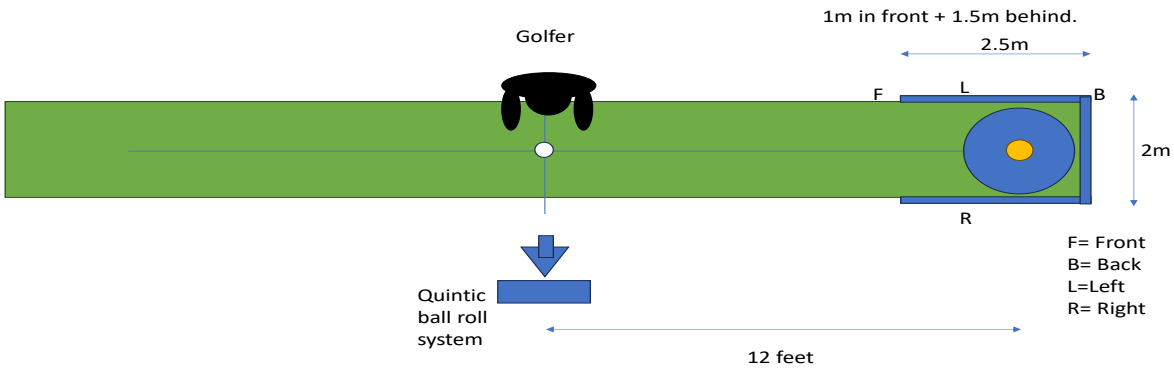

Figure 2: Layout of the putting area.

Figure 3: Calibration screen when all components of calibration were in the correct points.

Figure 4: Club Calibration.
Dots placed on the shaft and toe of the club, giving the feedback of the club angle and shaft lean on impact.

Figure 5: Measurement from toe to the middle of the putter head.

Shot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
left																									
right																									
front																									
back																									

Figure 6: Scorecard for coordinates of each shot to be recorded.

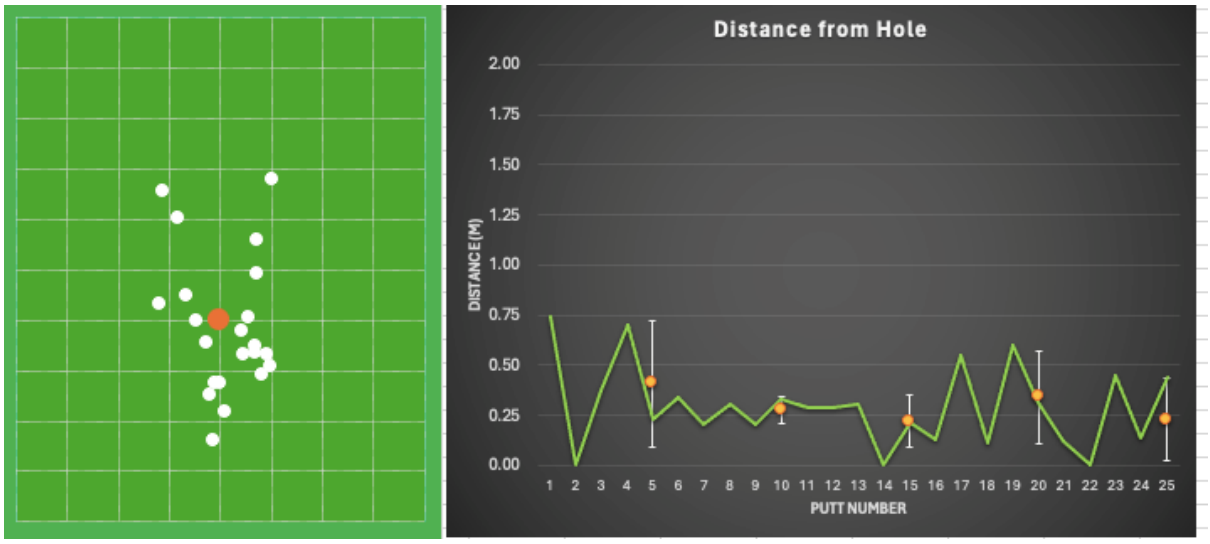

Figure 7: Example graphs for each participant after all shots were recorded.

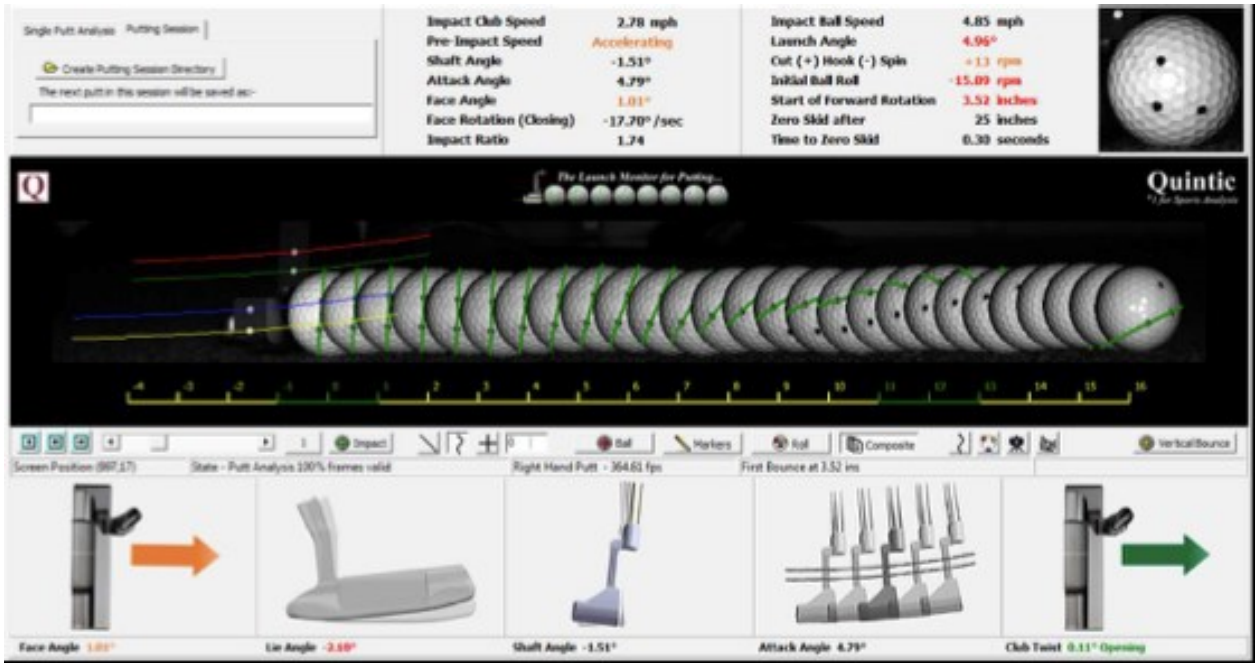

Figure 8: Feedback screen from each shot displayed on the screen connected to the Quintic ball roll system.

Results

Successful putts

The ultimate goal of this research was for participants to get the ball into the cup with a single putt as many times as possible. The Quintic technology group achieved 67 successful putts out of the total 250 shots - 26.8%. The control group achieved 53 out of 250 - 21.2%. The Quintic group was therefore more successful in this study overall compared to the control group, achieving 14 more successful putts – 5.6% more.

Also, we wanted to assess at what stage of the testing the most putts were made. We wanted to assess if the improvement was constant throughout. Table 1 shows at which points each group had the most putts made.

Shot number	Quintic	Control	Total
1st 5	9	6	15
2nd 5	15	11	26
3rd 5	16	10	26
4th 5	13	15	28
Final 5	17	12	29

Table 1: Breakdown of the putts made by each group in every 5 shots taken.

The total successful putts from both groups got progressively better, with the least amount made in the first 5, 15/250, 6% and the most made in the final 5, 29/250, 11.6% (table 1). However, there wasn't a consistent improvement throughout. The control group made the majority of their successful putts in the 4th set of 5 (table 1). The data shows that both groups achieved a higher success rate at the end of the session compared to the beginning (table 2).

Group	First 5 putts (successful)	Last 5 putts (successful)	% improvement
Quintic group	9	17	3.2%
Control group	6	12	2.4%

Table 2: percentage change in successful putts in the first 5 shots to the last 5 shots

Accuracy

Both groups showed improvements in overall accuracy from the first 5 shots to the last 5. One can infer from this that each participant adapted to the putting surface and became increasingly familiar and comfortable with the techniques required to have optimal speed and direction. This is shown in figure 9.

The Quintic group performed significantly better in the final 5 shots: $t= 4.485$, $p= 0.001$. The Control group also performed significantly better in the final 5 shots: $t=2.801$, $p=0.010$. This shows that the technology even over a short period was beneficial to the participants who used it (table 3). However, the full extent of how useful the technology was is not clear as the Control group still made significant improvements. The standard deviation shows that the control group had a smaller distribution of finishing points with the mean end point being closer (table 3). This suggests that their overall accuracy was better but couldn't make the perfect shot as often.

	Quintic		Control			
	Mean	SD	Mean	SD	t-value	p-value
Overall	0.561	0.524	0.518	0.464	0.704	0.245
Shots						
1st 5	0.868	0.604	0.827	0.547	0.272	0.394
2nd 5	0.585	0.575	0.449	0.42	1.151	0.132
3rd 5	0.464	0.485	0.442	0.427	0.141	0.445
4th 5	0.513	0.439	0.356	0.36	2.287	0.017
5th 5	0.373	0.380	0.507	0.416	1.655	0.058
Comparison	t-value	p-value	t-value	p-value		
Last 5 v First !	4.485	0.001	2.801	0.01		

Table 3: Full results table.

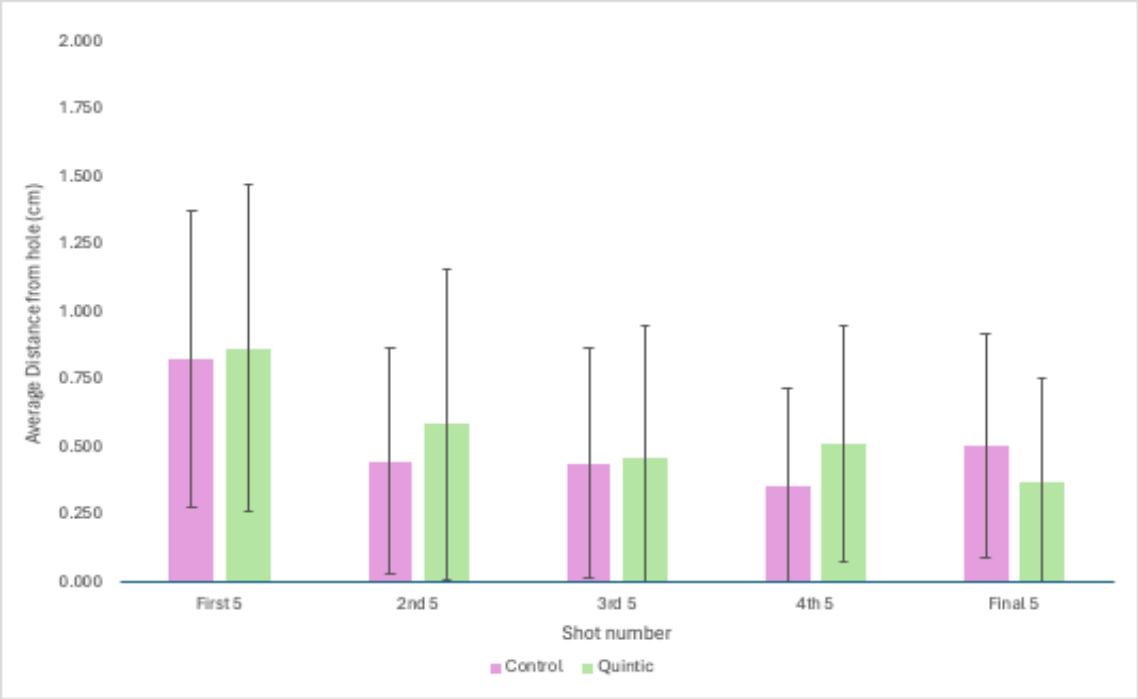

Figure 9: comparing the mean distance from the hole of every 5 shots taken for both Quintic and the control groups.

Discussion

Interestingly, when the results were evaluated overall, the mean distances of the Quintic group were further away from the hole than the control group. However, the mean of the last 5 shots taken by the Quintic group were significantly closer to the hole compared to the Control Group. This suggests that the performance of those golfers who used the Quintic system improved at a greater rate as a result using its feedback and adapting accordingly.

Stand out participants

One participant that stood out during the research was participant number 10. Starting with an average distance of 85cm to the hole in their first 5 putts, their last 5 balls were measured at only 12cm from the hole, with the last 3 putts all going in. This showed that understanding and taking on board what the technology was telling them meant they could make drastic improvements. They said, “by the last 5 shots I felt very comfortable of what was the correct speed and could focus on making good contact with the ball”. Although with the limitation that this was only when repeating the exact same shot – which would never be the case in a normal game of golf. When the control group carried out the study the technology was not used at all and although their performance improved, the improvement was less than for those using the Quintic. If this research was to be carried out again or the method used by coaches, it would be suggested to have the Quintic ball roll system available to just the coach in order to assess whether the misses were attributable to execution or the result of another factor. Participants would also tend to have hot patches where they would make multiple perfect putts in a row. For example, participant 4 made 7 successful putts, with 4 of these coming in a row. This was a common theme and suggested participants could find a good rhythm at certain times during the testing. This had no regular pattern, and it is unclear why it was common in many participants.

Technologies available

A study from Kooyman et al (2013) suggested that the use of sensors to track club movements improved the consistency of high skilled golfers but lowered their overall performance, and had the opposite effect on low skilled golfers, making them more erratic but with a higher percentage of made putts. Amer et al (2023) found the accuracy of putts when using virtual reality (VR) was significantly higher than putting in the real world. This suggested that the VR headset allowed any distractions to be removed and focus levels were constantly maintained. However, it was stated that the use of VR didn’t allow for the development of the motor skill meaning it could be considered useless for use as a training aid at this point. Research within this area is sparse and finding other research on whether technology has or has the potential to make a difference to improving putting skills and success is neither proved nor disproved. That’s what makes this research unique as its impact is not something that has been quantified objectively previously but instead players or coaches appear to have elected to use it based on a subjective hunch that it could make a difference and be of benefit.

Putting is a skill that takes years to master and many players never do. This study was limited to only 20 participants who only performed once over a single session that took around 30

minutes for each individual participant. Another study focused on whether technology had an impact over a longer period would be more beneficial. Many coaches now do use technologies like Quintic to give justification to their feedback. Coaches should also combine technologies to replicate real life scenarios and conditions. These include: the Zen Green Stage, which is used to work on reading the break and undulations of the green; the Sam Putt Lab, which will monitor the physiological movements during the swing such as weight movements from force plates. Combining these technology- based tools with the Quintic ball roll would give coaches the best way to assess exactly at which point of the shot the skill breakdown was. It also allows for the entire skill to be practiced indoors if accessibility outdoors was limited. Using a combination of these technologies could give the most valuable feedback to players and coaches (Fernandes et al, 2013). These technologies can be used by coaches and players at all levels. However, a certain understanding of how to interpret the feedback is required (Kooyman et al, 2013). A coach should look to use it with players who are wanting to concentrate on fine tuning a certain part of their stroke. It would not be of help to those who are still learning the motor skill and may cause confusion if their pre-existing technique is not good.

Limitations of the study methodology

Many participants commented on the speed differences compared to what they were used too. A limitation of this study therefore was the fact it was performed on an indoor putting surface. If it was to be conducted outdoors on a proper putting surface the participants would have had to deal with undulating greens with a truer roll. This would have presented a greater challenge because it would be unlikely as many made putts would have been made. Out of 20, 55% of the participants bettered the PGA average showing that the testing was potentially made too easy. Furthermore, putting on a surface all players are used to would have meant speed wouldn't have been as much of an issue. This would have then highlighted the discrepancies in the face angle more clearly and more focus could have been put on that aspect of the putt.

For this research the focus was on the face angle and how that affected the putt. However, the Quintic technology had more metrics that could have been utilised to give more feedback about the skill as a whole. The inclusion of these features such as clubhead speed and ball speed could have meant a more detailed breakdown of what was happening with each putt. Future research should therefore consider using these. Some participants using the technology also may have not fully understood what the data was showing and what the relevant adjustments were to improve. Future studies could give out prior lessons on what the technology is telling them, so no confusion is created. However, the ones who were very engaged in what the feedback was and understood what changes they could make to their technique saw the best improvements in results.

In this study handicap was taken but not accounted for and participants were randomly split, meaning all the players performed under the same conditions. This may have impacted on results. Even though all the players were experienced, the better players are likely to get more accurate end results. However, studies show players have different strengths of their game. For example, one low handicapper might consistently hit their approach shots very close,

leaving easy short putts (Dorsel and Rotunda, 2001). This may mean they don't rely on any putting skills to attribute to their low handicap. Opposingly, a higher handicap may have to rely on a strong putting game. This means the higher handicap player might actually be a better putter than a lower handicapper. The low handicap may simply just be able to hit it further (Hellström, 2009) and more accurately (Finley and Halsey, 2004) increasing the ease of the making the green in regulation.

The research was very repetitive and especially for the control group. This was because they didn't have the technology to interact with. By the last 5 shots the participants may have become bored with the repetitive nature of the task. This may be a reason why their successful putt scores dipped for the last 5 shots (figure 7). Wolff et al (2021) found that boredom and low arousal leads to a reduction in performance. Making it more interactive may lead to truer data. It was clear that the first 5 were the worst, then the next 15 shots were all very similar on average and a final spike happened in the Quintic group as they had time to make the relevant changes and could focus on finishing well. A further development may have been to make it more competitive (Murayama and Elliot, 2012) with a leader board. This may have driven participants to focus and try their hardest for the entirety of the study.

Does this research really matter?

While it is clear that improvements have been made, the average distance from the hole in the first 5 shots were 87cm for the Quintic group and 82cm for the control group. By comparison the averages for the last 5 shot were 37cm for the Quintic group and 51cm for the control. These distances on a golf course are insignificant - both would make for an easy finish to the hole. The research therefore should a focus on increasing the number of putts which are successful as that is the goal if the player's score for the round is to be lowered. If this was to be carried out again it could be suggested to simply record which putts were made or missed.

Conclusion

Importance of this study

This study was designed to investigate whether the use of technology in training whereby a player is provided with immediate feedback after they have taken a putt, will lead to greater improvement in their success and accuracy than if they had not had access to this feedback.

The study is important because it is evident that minor adjustments can have a significant impact on performance. Honing skills, especially regarding the club face at contact, is difficult for a coach without the assistance of technology to notice as there is such a small difference between good and bad. It is also important because there is so little evidence currently relating to the impact of technological training aids on putting skill development.

This research found that the use of technology during a putting task is beneficial in achieving more successful putts. It however did highlight that when the putt was missed, the ball rolled a greater distance from the hole on average compared to the control group. Although it was clear that over time both groups became more comfortable with the task, the Quintic

technology group were much more accurate and consistent during the last 5 shots compared to the control group. This suggests that the real-time feedback allowed for immediate corrections, leading to improved future putts.

Real world application

This research can be used by players and coaches in the real world to improve understanding of how to train in order to become better at putts from this distance. Improvements will not be limited to only this distance, as the understanding of the technique and the skill acquisition will allow for all distances of putting to be improved. A combination of different technologies could be used to tailor to a player's training regime and can maximise improvements. Therefore, further studies should be carried out to assess if this is the best way to train. Different distance putts may need different training needs, understanding this may help tailor training sessions to achieve the best outcomes.

Studies limitations

This research does also highlight certain limitations and opportunities for the research methodology to be developed so that the results are even more useful, for example: This study was based on one episode of training. It could be expanded to include more episodes over time. This study was conducted inside on artificial putting surface. Consideration could be given to environmental factors, such as conducting the research outdoors on a green, instead of indoors. This could give real world insights into performance, as well as allowing the players to practice on the same surface they will be competing on. Working on all the aspects of the putt such as the undulations, speed and environmental conditions like high winds would be more realistic and therefore potentially more useful. The PGA average for balls holed from 12 feet is 22%, however if a PGA professional was to conduct this task, I believe that percentage would be much higher. Research into the long-term effects of training with technologies and how they impact real world results, running the research over multiple different sessions would show more depth and breadth of results.

Also, handicap was not accounted for. Even though all participants were experienced golfers, there was still a big difference in quality between some participants. A lower handicap player would be expected to do better at this task as they are a better overall golfer. One way to potentially resolve this is issue would be getting the same participants to perform the task twice, once with technology, once without.

In conclusion, whilst the study contributes insights into the effects and roles of technology used to improving putting performance, it highlights the vast research that is needed to gain a full understanding. By using advanced tools and strong methodology, golfers could potentially enhance performance, ultimately being more successful and shifting focus onto a part of the game that seems neglected. This is important at all levels of the game, amateur players may get more enjoyment from each round as their scores are lower. Professionals may find that slight edge that allows them to win against the very best in the world.

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