Supplemental Material

Towards an Understanding of AR visualization for sports skill training

This document provides supplementary material for our study results. We categorize the contents into 3 parts, including qualitative analysis, quantitative analysis, and study surveys.

1 Supplemental Materials

1.1 Qualitative analysis

Figure 1: *Upset plots showing the qualitative coding results for survey responses. Top Panel: survey responses for the 2D condition. Bottom panel: survey responses for the AR condition.*

#	ID	Question	Response	Participant	Final Codes
Particip					
1	1	What information in 2D visualization are most useful	Having the arc displayed as numbers	P1	number - a...
2	11	What information in AR visualization are most useful?	Evaluating shot direction and alignment; Train shooting form to adapt to ideal arc	P1	extra shot d... direction alignment informed de...
3	21	Which features (if any) are missing that would make 2D tool more useful / usable?	Height of where the ball was released; Rotation	P1	extra shot d... release point spin
4	31	Which features (if any) are missing that would make AR tool more useful / usable?	Displaying numeric value the arc of the previous shot. It's not super difficult to compare the arc visualization but it would help more to know exactly what the angle was. Also something related to release point	P1	after-fact-c... number - a... extra shot d... release point
5	41	Open Comments - final thoughts on 2D tool	It's easier to use and doesn't require a headset, but the visualization felt more realistic with the 3D tool.	P1	ease of use no headset ... not immersi... non disrupti...
6	51	Open Comments - final thoughts on 3D tool	I think it's a great tool. The only barrier (besides cost) is that the headset is prone to move a little no matter how tight you adjust it, so it's not super comfortable and something you have to get used to.	P1	discomfort intrusive he... useful
7	61	Oral feedback during practice - AR	When I feel fatigued, it helps to keep the arc not being too flat. Really helps with alignment, sometimes I don't even realize I'm not at the center. Immediately know you're off. I aim at the hoop, but the glasses	P1	informed de... insight gen... overthinking shape
8	70	Do you have any feedback on your shooting experience today? (Session Survey 2D)	It felt less distracting without the headset, but I also miss having the 3D visualization to evaluate the shooting arc of the previous shot and using it as a reminder to follow through.	P1	non disrupti... shape no headset ...
9	77	Do you have any feedback on your shooting experience today? (Session Survey AR)	In the first 2 rounds, the headset was distracting, especially when it was slipping off. It took a bit of time to get used to it. When I felt more comfortable with the headset, it was very useful to align my shot	P1	intrusive he... discomfort useful informed de... alignment

Figure 2: *Demonstration of user responses and codes in Airtable.*

1.2 Quantitative analysis

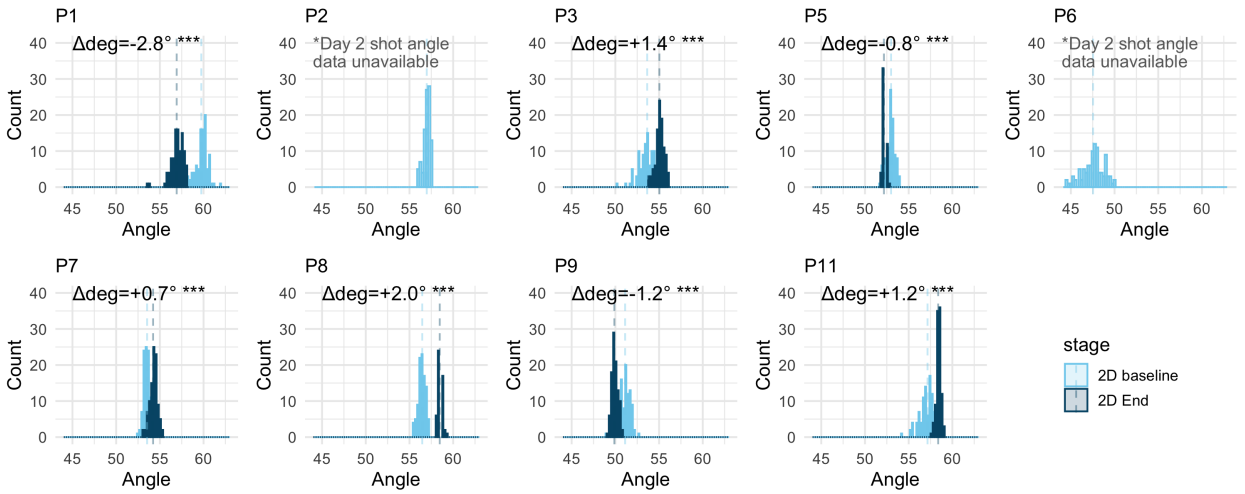

Figure 3: *Shot angle histogram between 100 shots in 2D regular baseline (light blue) and last 100 shots in 2D end (dark blue) of all participants. The annotation in each panel describes the angle difference and the standard deviation of each condition. 5 out 7 participants had a different shot angle (Δdeg> 1°) in the end. *** indicates p<0.001.*

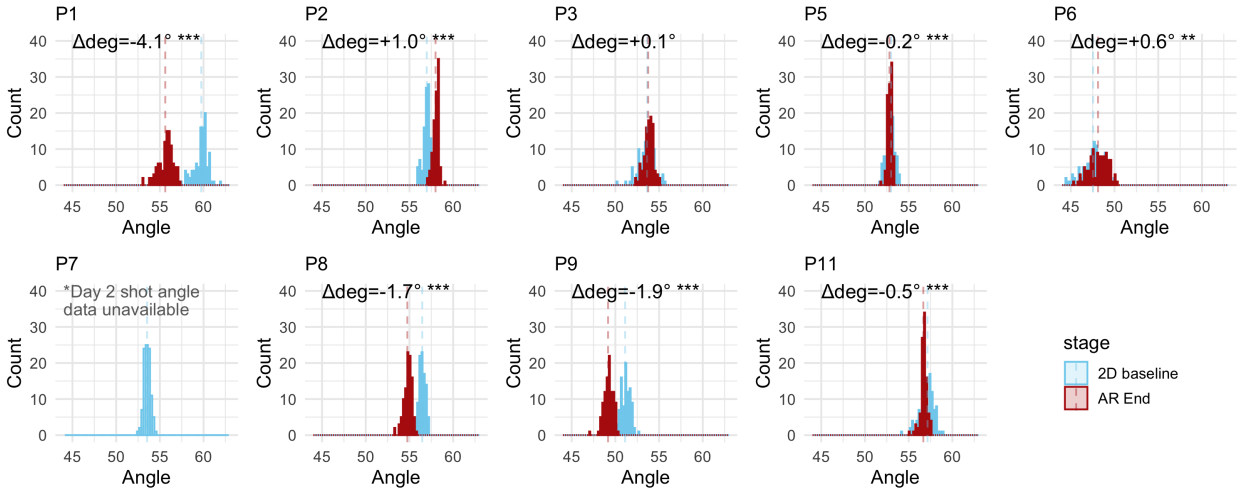

Figure 4: *Shot angle histogram between 100 shots in 2D regular baseline (light blue) and last 100 shots in AR end (red) of all participants. The annotation in each panel describes the angle difference and the standard deviation of each condition. 3 out 8 participants had a different shot angle (Δdeg> 1°) in the end. *** indicates p<0.001.*

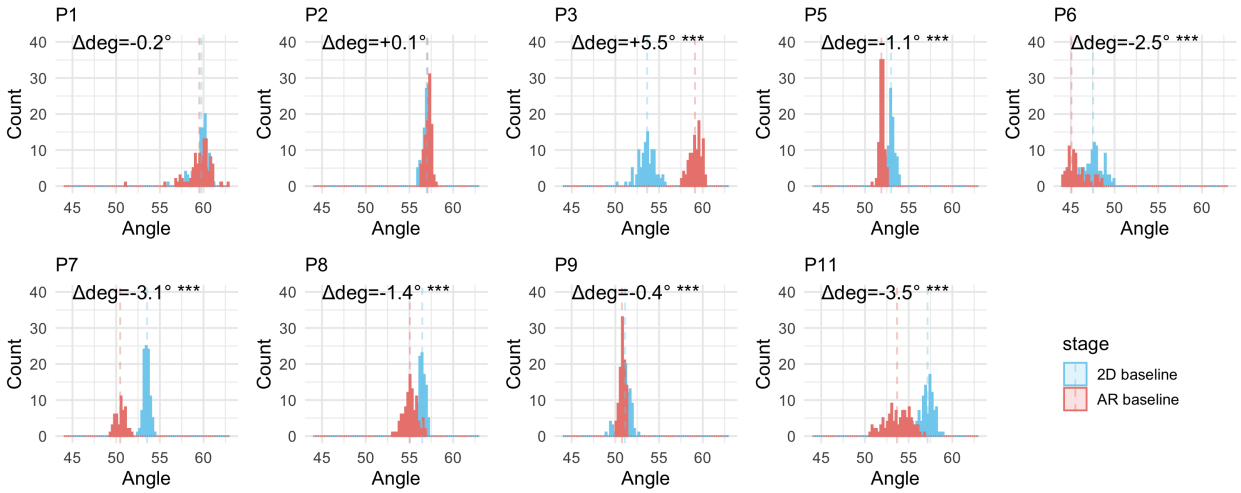

Figure 5: *Shot angle histogram between 100 shots in 2D regular baseline (blue) and in AR baseline with HMD (red) of all participants. The annotation in each panel describes the angle difference between each condition. *** indicates p<0.001.*

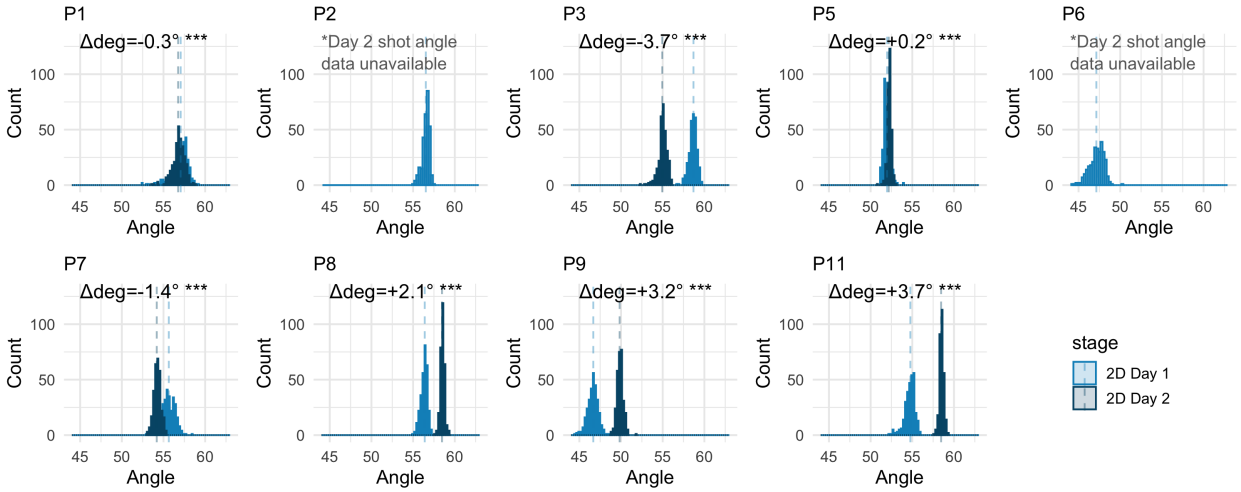

Figure 6: *Shot angle histogram between 300 shots on 2D day 1 and day 2 of all participants. The annotation in each panel describes the angle difference between each condition. 5 out 7 participants had a different shot angle (Δdeg> 1°) across days. *** indicates p<0.001.*

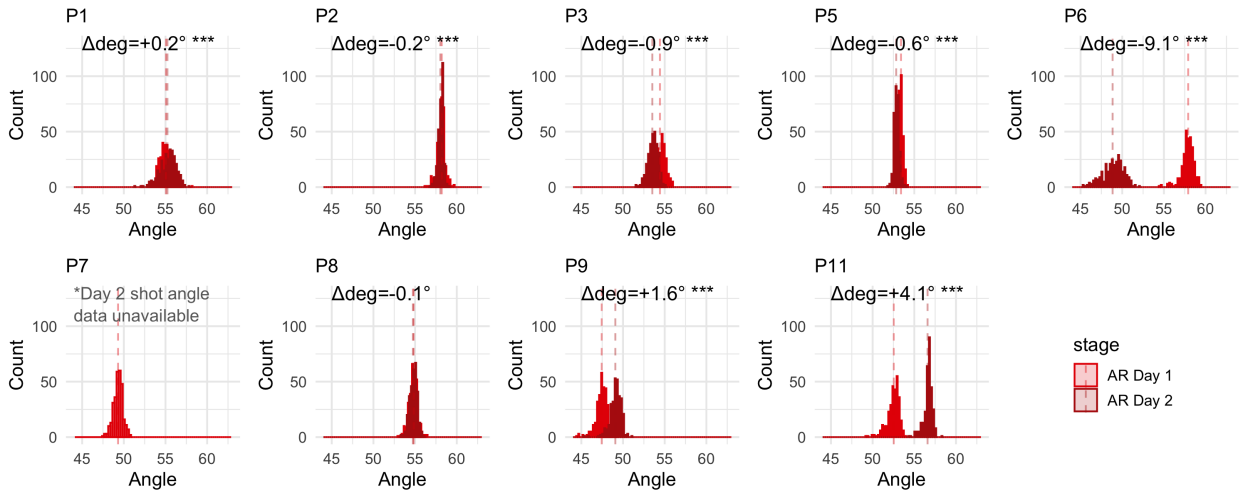

Figure 7: *Shot angle histogram between 300 shots on AR day 1 and day 2 of all participants. The annotation in each panel describes the angle difference between each condition. 3 out 8 participants had a different shot angle (Δdeg> 1°) across days. *** indicates p<0.001.*

1.3 Survey

The following are surveys we used to collect user feedback throughout the training experiences, including a pre-study survey on participants' background, post-study surveys for both 2D and AR tool evaluation, and a follow-up survey on user goals and ratings.

[Shooting ARc] Pre-study survey

Mark or circle your answers

BACKGROUND					
1. What is your gender?					
male		female		non-binary	
2. How old are you?					
18-25	25-34	35-44	45-54	55-64	65-74
3. How long have you played basketball?					
< 3 years	3-5 years	5-10 years	> 10 years	Other:	
4. What level of basketball player do you consider yourself to be?					
Beginner	Intermediate	Recreational	Competitive	Professional	
5. How frequently do you play basketball?					
> 3 times / week	1-3 times / week	Every other week	Once per month	Other:	
6. Which team do you play for? (if any)					
7. Do you have any injury?					
8. Have you had any previous experiences with Augmented or Virtual Reality?					
Yes		No		Not sure	
SHOOTING EXPERIENCE					
1. How many shots do you shoot in a shooting training session?					
< 100	100~300	300~500	> 500	Other:	
2. How long is your shooting practice session?					
< 15 mins	15~30 mins	30~60 mins	> 1 hour	Other:	

3. Please indicate how well you agree with the following statement: "I am a skilled free-throw shooter"					
Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	Other:
4. How important is free-throw shooting performance for you?					
Extremely important	Very important	Moderately important	Slightly important	Not at all important	Other:
5. Do you know your free throw percentage?					
Yes: _____			No		
6. Do you know your free-throw shot angle?					
Yes: _____			No		
7. Do you have a targeted free-throw shot angle?					
Yes: _____			No		
8. What tool do you mainly use to keep your shooting record? (Check all that apply)					
Verbal counting	Paper	Mobile App: _____	I do not keep record	Other:	

PHYSICAL CONDITIONS	
1. When was the last time you were physically active?	
Day 1:	Day 2:
2. Do you feel physically fatigued?	
Day 1:	Day 2:

[Shooting ARc] Post-study Survey- 2D visualization

Check the answer

1	2	3	4	5
1. How easy was it to understand the main idea behind Shooting ARc's method for 2D visualization?				
1: very hard to understand				*5: very easy to understand*
2. How easy is it to learn how to use the Shooting ARc user interface on a side-view display?				
1: very hard to learn				*5: very easy to learn*
3. How easy is it to understand the 2D visualization for free-throw shooting?				
1: very hard to understand				*5: very easy to understand*
4. How useful is 2D visualization on the display for evaluating your previous shot performance?				
1: not useful at all				*5: very useful*
5. How easy it is with 2D visualization on the display to adjust your desired angle?				
1: not easy at all				*5: very easy*
6. How easy it is to use 2D visualization on the display to match your shot angle with the desired angle?				
1: not easy at all				*5: very easy*
7. How useful it is 2D visualization on the display for improving your shot arc / angle?				
1: not useful at all				*5: very useful*
8. How useful is 2D visualization on the display for improving your shooting percentage?				
1: not useful at all				*5: very useful*

9. What information in the 2D visualization are most useful?				
10. How useful is Shooting ARc in its current form to you?				
1: not useful at all				*5: very useful*
11. How likely are you going to use Shooting ARc for free-throw training?				
1: not at all				*5: very likely*
12. Which features (if any) are missing that would make this tool more useful / usable? *(Please order by importance)*				
13. Imagine all missing features are implemented, how likely are you going to use Shooting ARc for free-throw training?				
1: not at all				*5: very likely*

12. Is this kind of 2D visualization currently possible with other tools? *(Please name the other tools and order them by their similarity to Shooting ARc)*	
Yes: _____	No / I don't know.

Do you want to share with us anything else?

Thank you for your participation and feedback!

[Shooting ARc] Post-study Survey- 3D visualization

Check the answer

1	2	3	4	5
1. How easy was it to understand the main idea behind Shooting ARc's method for 3D visualization in AR?				
1: very hard to understand				*5: very easy to understand*
2. How easy is it to learn how to use the Shooting ARc user interface in Hololens?				
1: very hard to learn				*5: very easy to learn*
3. How easy is it to understand the 3D visualization for free-throw shooting?				
1: very hard to understand				*5: very easy to understand*
4. How useful is 3D visualization in AR for evaluating your previous shot performance?				
1: not useful at all				*5: very useful*
5. How easy it is in AR to adjust your desired angle?				
1: not easy at all				*5: very easy*
6. How easy it is to use 3D visualization in AR to match your shot angle with the desired angle?				
1: not easy at all				*5: very easy*
7. How useful it is 3D visualization in AR for improving your shot arc / angle?				
1: not useful at all				*5: very useful*
8. How useful is 3D visualization in AR for improving your shooting percentage?				
1: not useful at all				*5: very useful*

9. What information in the 3D visualization are most useful?				
10. How useful is Shooting ARc in its current form to you?				
1: not useful at all				*5: very useful*
11. How likely are you going to use Shooting ARc for free-throw training?				
1: not at all				*5: very likely*
12. Which features (if any) are missing that would make this tool more useful / usable? *(Please order by importance)*				
13. Imagine all missing features are implemented, how likely are you going to use Shooting ARc for free-throw training?				
1: not at all				*5: very likely*

12. Is this kind of 3D visualization currently possible with other tools? *(Please name the other tools and order them by their similarity to Shooting ARc)*	
Yes: _____	No / I don't know.

Do you want to share with us anything else?

Thank you for your participation and feedback!

Shooting ARc - Followup Survey

* 1. What is your name?

* 2. What were your *main* goals when using the **AR**system? Rank them in order of importance, using N/A for any that don't apply.

Improve my shot accuracy	☐ N/A
Match my target angle	☐ N/A
Improve my form when throwing the ball	☐ N/A

3. Did you have a goal other than ones listed above? If so, what was it?

* 4. On a scale of 1 to 5, how helpful was the AR visualization in reaching your goals?

1 Star 2 Stars 3 Stars 4 Stars 5 Stars

Please explain your rating.

* 5. Please share any additional thoughts on your interaction with the AR visualization.

* 6. What were your *main* goals when using the **2D**system? Rank them in order of importance, using N/A for any that don't apply.

Improve my shot accuracy	☐ N/A
Match my target angle	☐ N/A
Improve my form when throwing the ball	☐ N/A

* 7. Did you have a goal other than the ones listed above? If so, what was it?

* 8. On a scale of 1 to 5, how helpful was the **2D**visualization in reaching your goals?

1 Star 2 Stars 3 Stars 4 Stars 5 Stars

Please explain your rating.

* 9. Please share any additional thoughts on your interaction with the **2D** visualization.

Done