#140
Improve the effectiveness of design meetings with smartphone AR

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AEC Industries and Project Aims

Augmented Reality on different hardwares

Prototype Development

Testing Method

Results & Discussions

Conclusion and future work

Architecture, Engineering & Construction Industries

8% of NZ's total GDP[1]

10% of NZ's total employment[1]

Collaborations with different stakeholders[2]

Ineffective Design meetings in AEC Industries

Causes of ineffective design meetings:

High Cognition Costs[3]

Variations in interpretation

Missed Errors

Obscure and Unappealing

Project Aims

To determine the prototype's ability to facilitates the user's visualization process

To assess the effects of smartphone AR on the user's ability to communicate effectively

To investigate whether mobile devices provide similar benefits as Hololens

Augmented Reality (AR)

AR allows users to overlay virtual content onto the real world.[7]

Benefits:

Interpretation

Reduction in cognition costs

Visualisation

Reduction in misunderstandings

Alternating Perspectives

Effective communication[8]

Hardware for Augmented Reality

Head-mounted devices

Low Accessibility

Low situational awareness

High monetary costs

Low degree of intuitiveness

Hand-held Devices

High Accessibility

Moderate situational awareness

Low monetary costs

High degree of intuitiveness

Modes of the developed prototype

Tutorial

Information for all levels of experience

Taught prototype use

Interaction with virtual buttons

Trial Rooms

Kitchen Room & Lounge

House Models

First, Second and Third Floor

Functionalities of the developed prototype

Colour

Red, Green and Blue

Emphasise on elements of high concern

Delete

Eliminate unwanted elements

Undo

Revert on size, colour, movements and elements

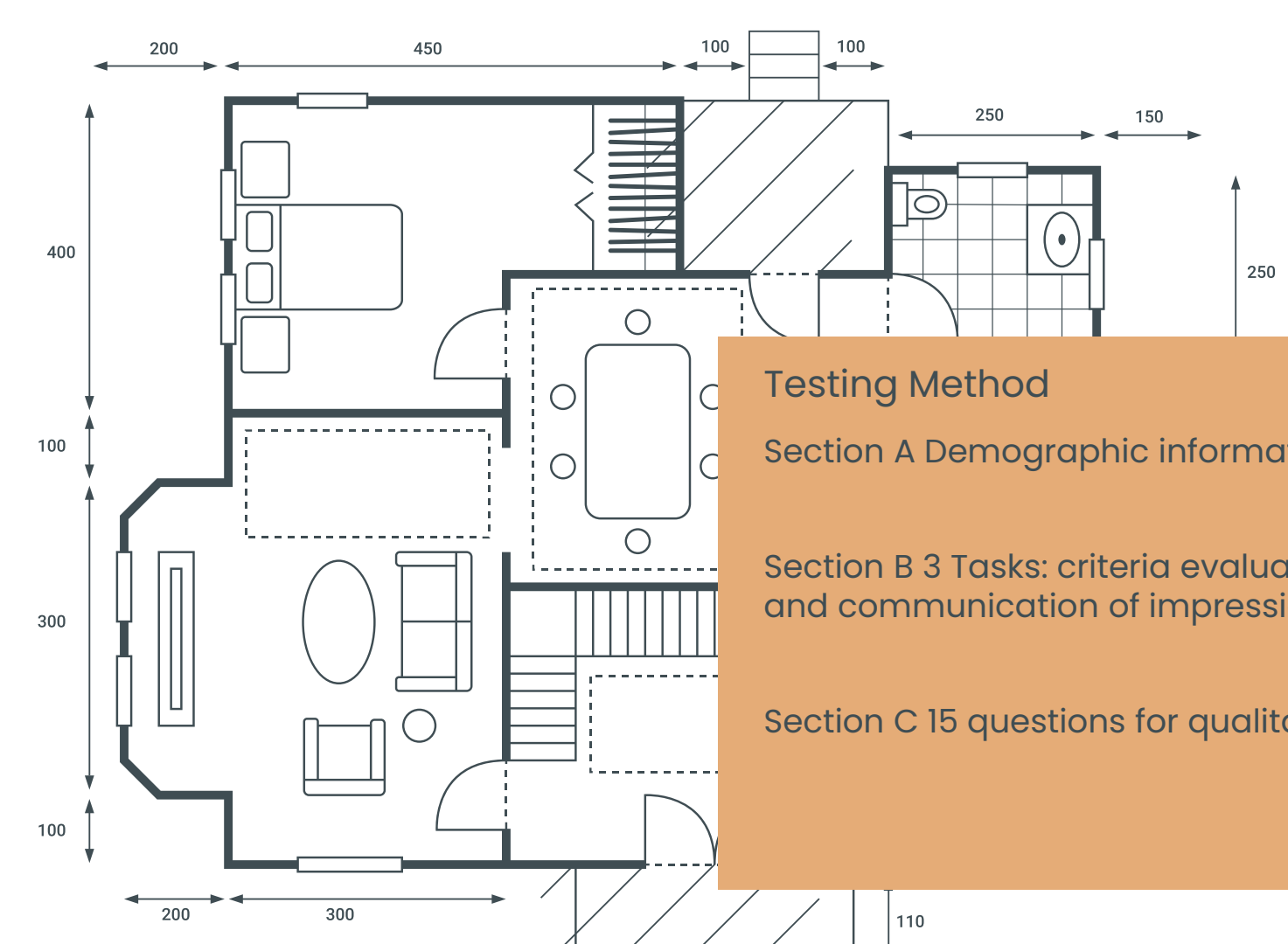
Manipulate

Two-Finger Gestures

Rotate about the x-axis

Translate about all axes

Size adjustment on models



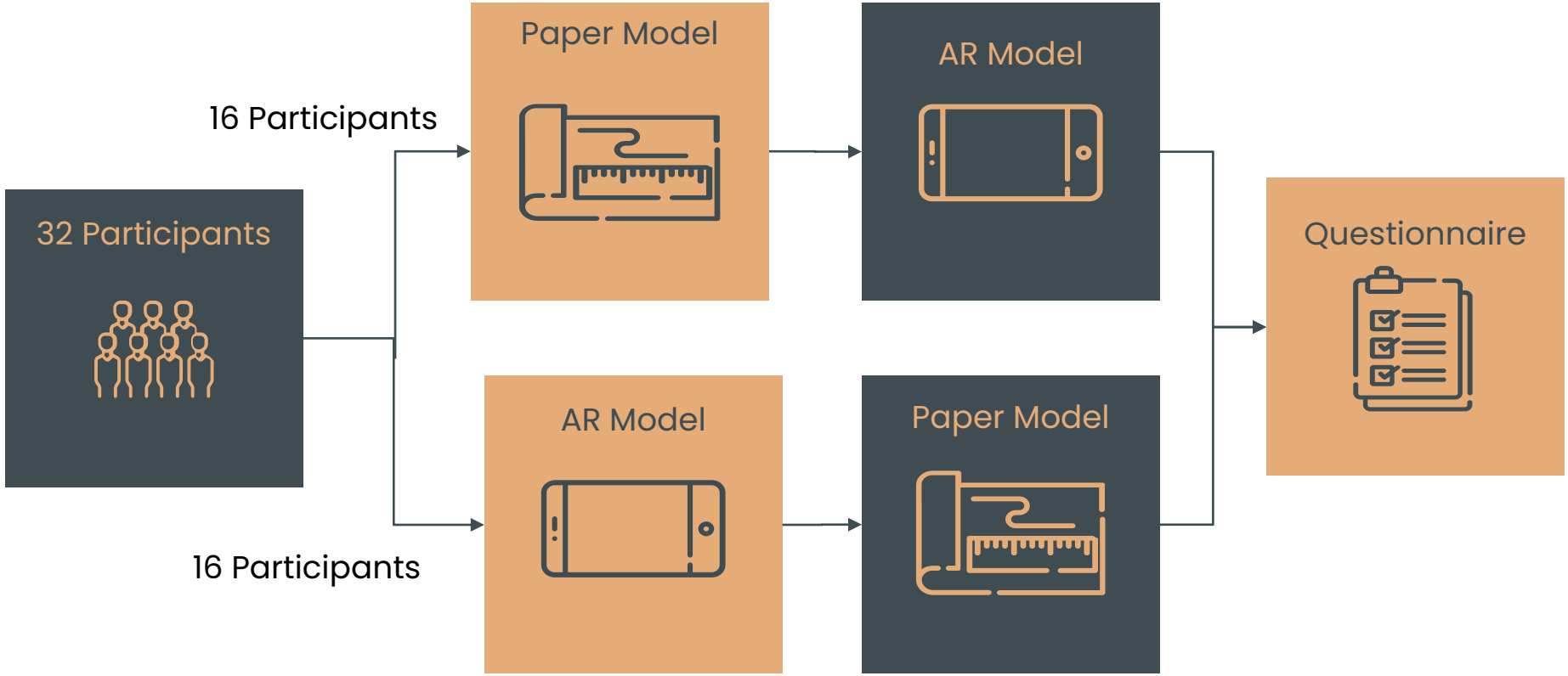
Testing Method

Section A Demographic information

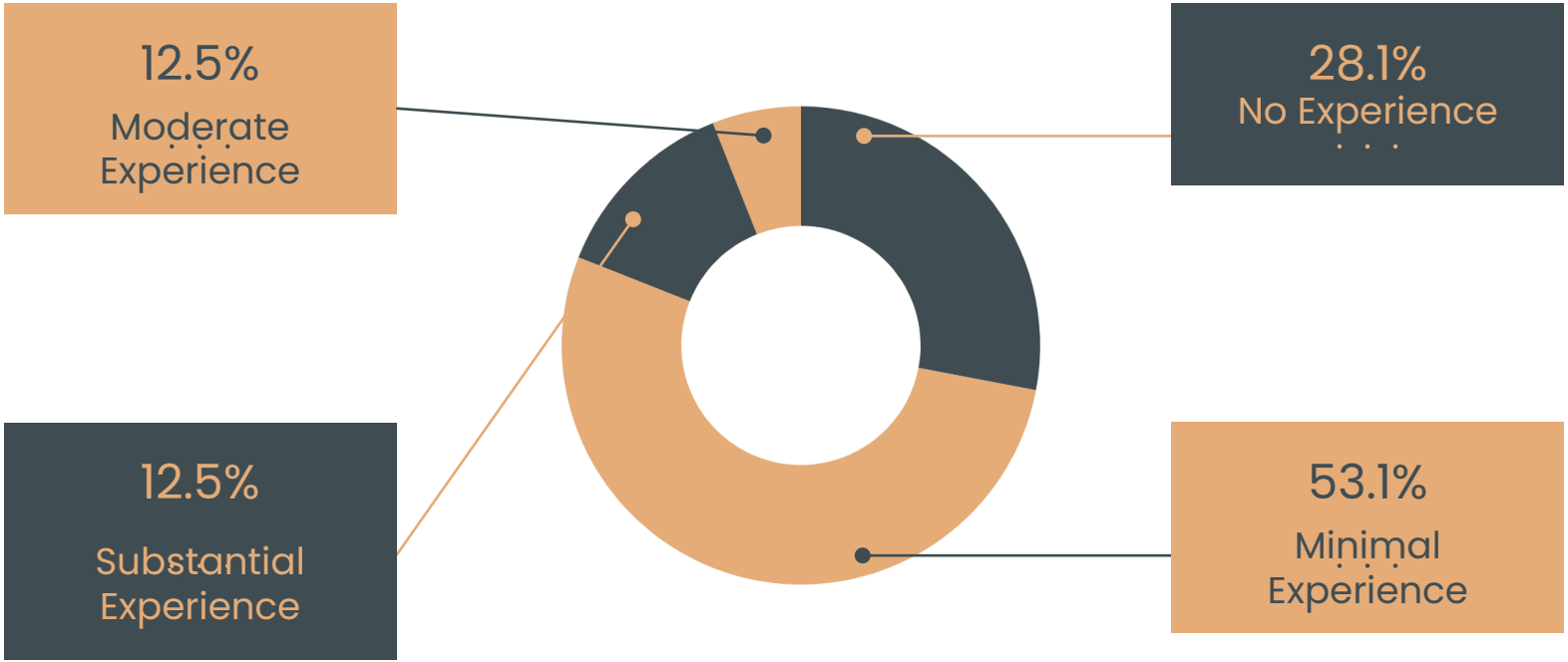
Section B 3 Tasks: criteria evaluation, making changes, and communication of impressions

Section C 15 questions for qualitative impressions

Testing Method - Counterbalanced Measures Procedure[4]

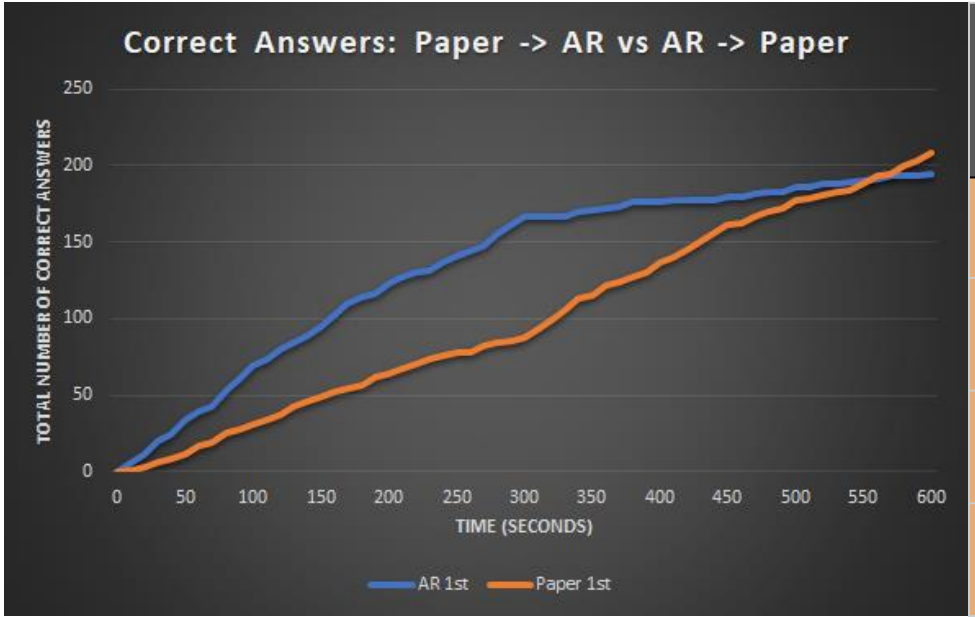


Results - Section A - Previous AR Experience



Results - Section B - Task 1

Comparison of Speed and Accuracy of identifying features



	Paper First		AR First	
	Paper mean	AR mean	AR mean	Paper mean
Average correct Answers	5.63	7.25	10.69	1.81
Average incorrect answers	1.19	0.44	0.44	0.75
Average confidence (correct)	7.90	8.96	8.76	7.15
Average confidence (incorrect)	5.63	6.00	6.67	4.33

Results - Section B - Task 1

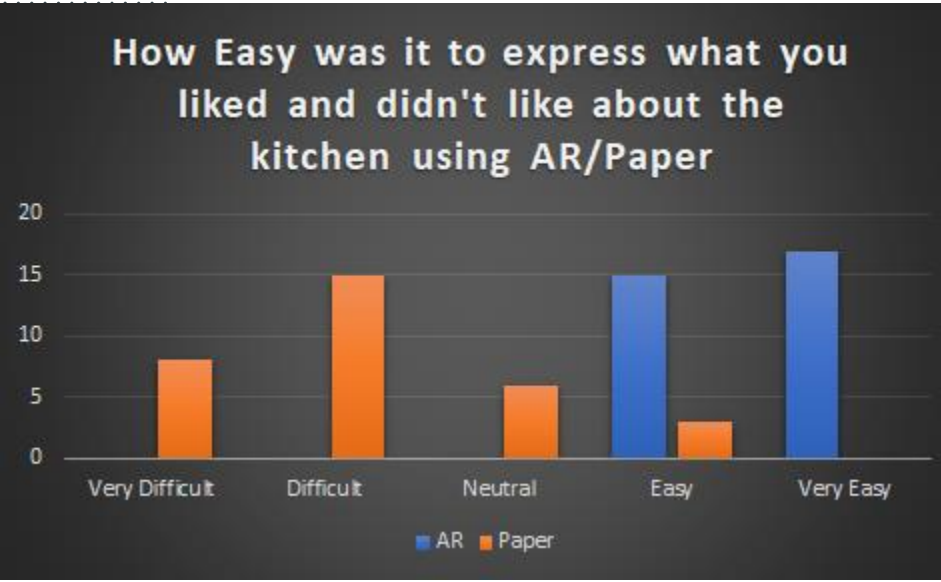
Criteria/Features	Paper (1st)	AR(2nd)	AR (1st)	Paper(2nd)
Window numbers	11	5	15	0
Windows floor to ceiling	7	5	14	1
2 Double doors	8	5	15	2
10+ Object to sit	11	5	14	2
4 types of seats	3	13	11	2
8 lights	10	6	16	0
Chair not facing window	8	8	16	0
Chairs collision	5	11	16	0
Table/Chair Collision	1	15	12	0
Table Floating	0	7	1	2
Toilet on deck	4	12	15	1
TV Orientation	6	10	10	6
Furnace Orientation	1	10	5	9
Cabinet Orientation	5	11	12	3

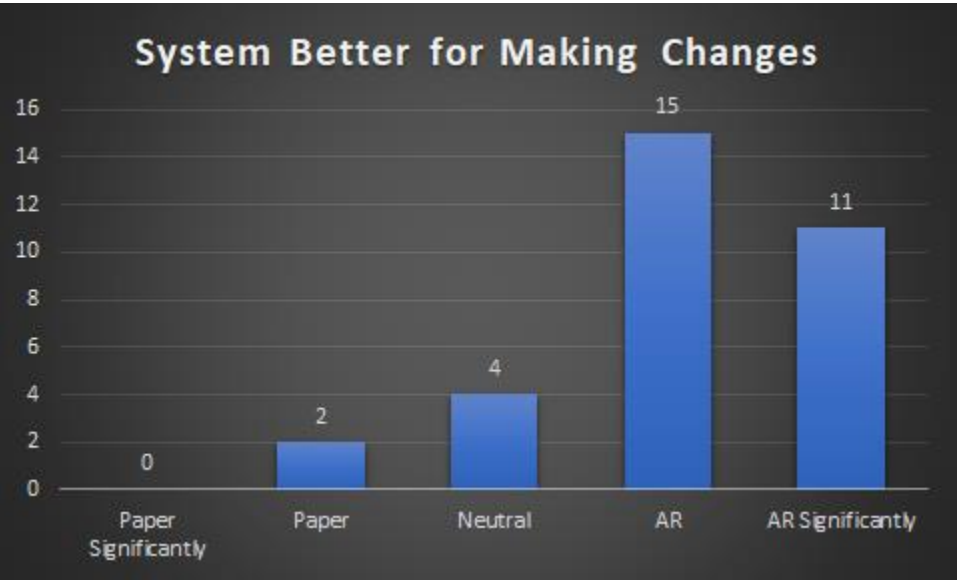
AR users frequently identified violations that weren't explicitly mentioned

Specific Criteria were found at a similar frequency by both AR and Paper

McNemar & Fisher's Exact Test [5]

Results - Section B - Task 2 and 3





Results - Section C

Question	AR	Paper
1, 5. How easy would the model be for a non-engineer to understand	100%	12.5%
2, 6. How easy was it to visualize the room's exterior	90.7%	3.1%
3, 7. How easy was it to visualize the buildings contents	100%	6.3%
4, 8. How easy was it to express what you liked/didn't like about the kitchen	100%	9.4%

- Questionnaire indicated participants favoured the AR model in every dimension (Wilcoxon signed-rank, $p<0.05$)[6]
- Participants were still able to communicate in a natural manner while using the AR

Conclusion

AR improves the visualization capabilities of users

The AR system received more positive feedback than the Paper model

AR users are able to communicate in the same way Paper users do

Smartphone AR reduces capital costs and accessibility compared to head-mounted devices such as Hololens

Thus, AR has potential use in AEC design meetings

Limitations

Simplicity

Trial contained model with easy to find errors

Collaboration

The prototype did not have collaboration functions

Hololens Comparison

Hololens was not used in the experiment, may not be suitable to draw conclusions

Future Works

Complexity

Similar trials with more complex models

Markerless AR

Allow the model to augmented without image target

Collaboration

Add Collaboration functionality for multiple users

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