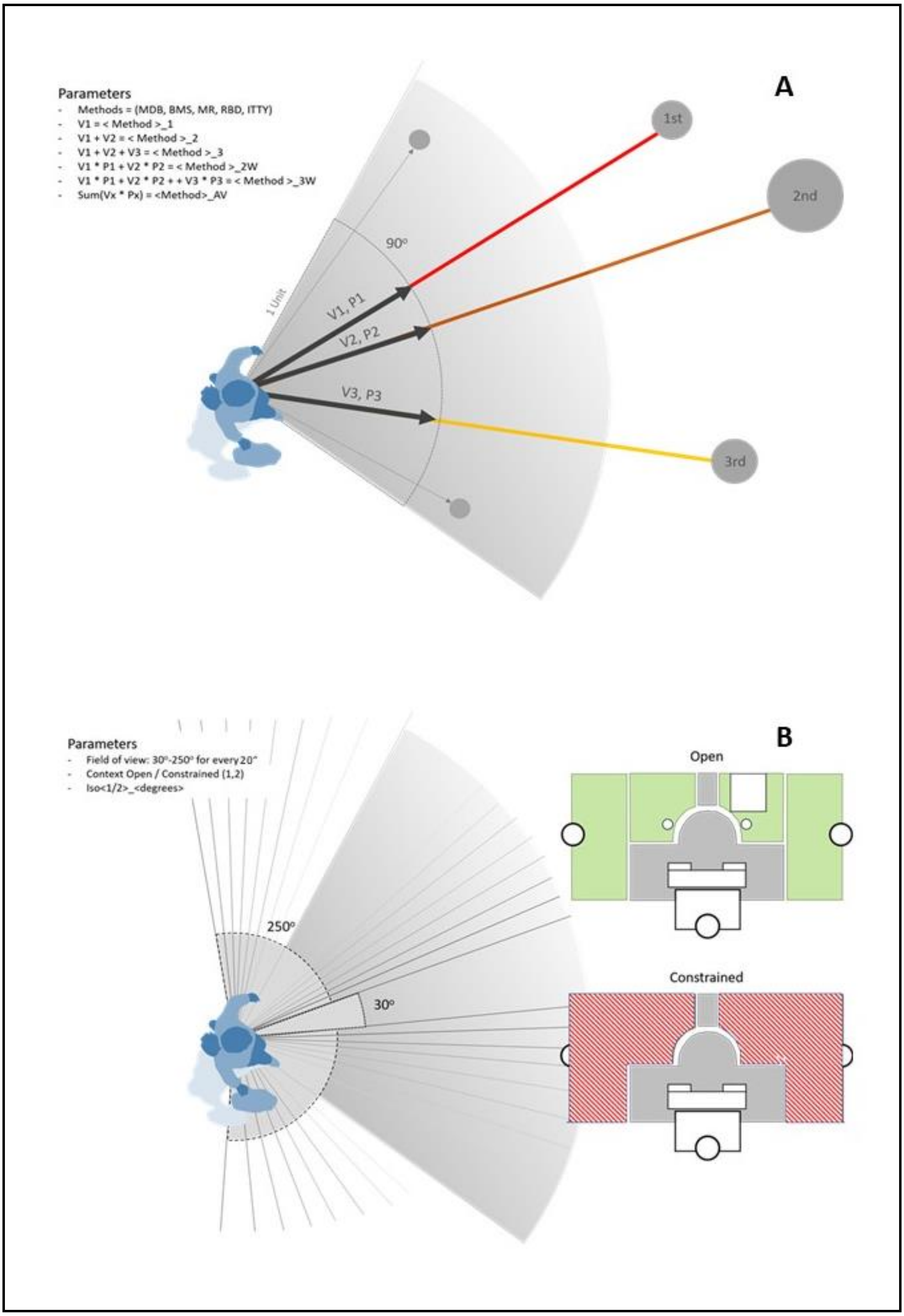

Figure 5.

A: All parameters used in the Saliency model; each parameter was tested for each of the 5 Saliency algorithms. V1: the vector pointing towards the most salient object, V2: to the second, V3: to the third. P1, P2, P3: different weightings used in the weighted saliency model. BMS: Boolean Map based Saliency, ITTY: Saliency ToolBox, MDB: Minimum Barrier Distance, MR: Manifold Ranking, RBD: Robust Background Detection.

B: All measures used for the isovist model. Range: 30 – 250 degrees, every 20 degrees. These were tested in both an Open and Constrained for vision and movement (i.e. excluding semi-accessible, visible areas) model. The plan view on the right is showing which areas where obstructed for the constrained model in Red.

3. RESULTS

Unfiltered dataset (n=3044 steps, 0-180 degrees)

No measure of Saliency or Isovist analysis had statistically significant correlation with the observed data, in the unfiltered dataset.

Change of direction between 5 – 45 degrees (n=1280 steps)

Both Saliency and Isovist were correlated with the observed change in direction (Figure 6). Three of the five Saliency methods (MDB, RBD, ITTY) shown negative correlation in at least one parameter (first vector, combination or average); the degree of correlation differed slightly between different saliency detection methods. Overall, the best performing saliency method was MDB_1 with a negative correlation of R=0.11 (p <0.001) when using the vector of the most salient object. For the Isovist, only one parameter (Iso2_30Lon: Isovist with 30 degrees field of view) was significant, with a positive correlation R=0.08 (p=0.038). To minimise negative bias, a second more constrained for vision and movement dataset where the spaces that are visible but not so easily accessible (covered with grass) were treated as obstacles was used; this did not lead to significant improvement in performance, with only one measure again (30 degrees) reaching statistical significance.

Finally, a combination of Saliency and Isovist was tested combining the best performing models for each method. As Saliency had negative correlation (detractor) the following combined model was used:

Combined Model = [Isovist] – [Saliency]

The combined model surpassed all other methods; for change of direction between 5-45 degrees, R=0.15 (p<0.001).

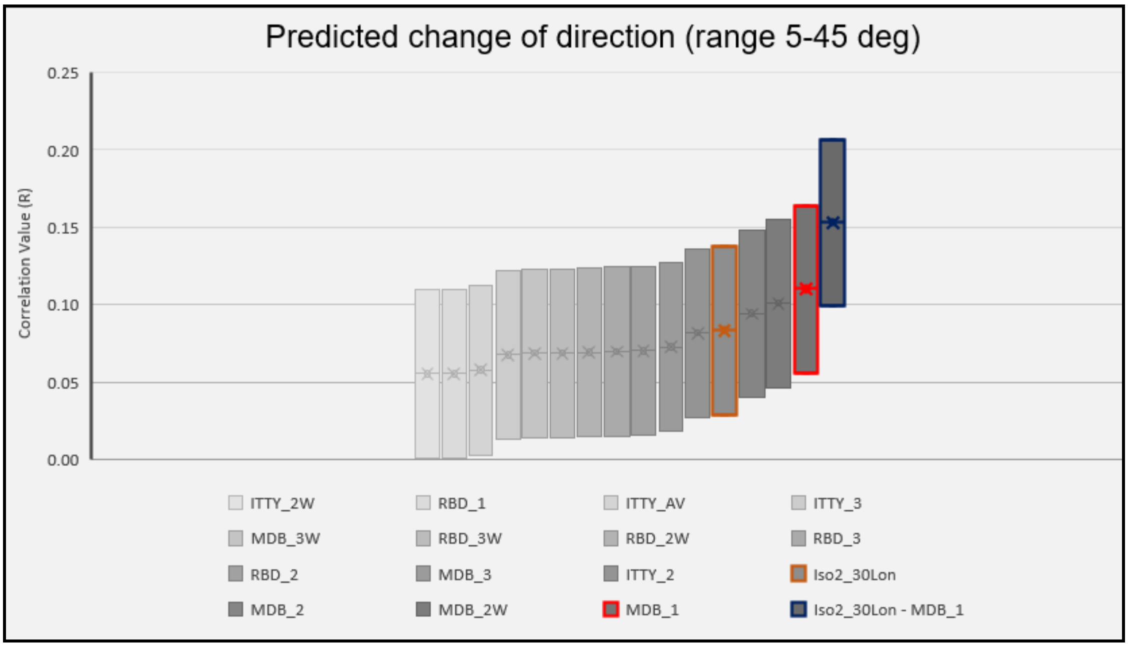

Figure 6. Absolute correlation values between the different Saliency and Isovist measures and observed data for Change of direction between 5-45 degrees. Note the Saliency results had negative correlation, but their values where flipped to be comparable with the Isovist. Red highlights the best performing Saliency method and Orange the best performing Isovist method; Black highlights the combination of best performing Saliency and best performing Isovist method.

Change of direction between 10 – 45 degrees (n=604 steps)

For both Isovist and Saliency, results improved when constraining the dataset to change of direction between 10-45 degrees, with similar inner dynamics; saliency models exhibiting negative correlation thus saliency acting as a detractor and a single Isovist model with a positive correlation. The best Saliency method was again MDB_1 with negative R=0.15 (p<0.001) and the best isovist measure Iso2_30Lon with positive R=0.10 (p=0.018). The combined model again outperformed single measures with R=0.19 (p<0.001). The results for all measures used is seen in Figure 7.

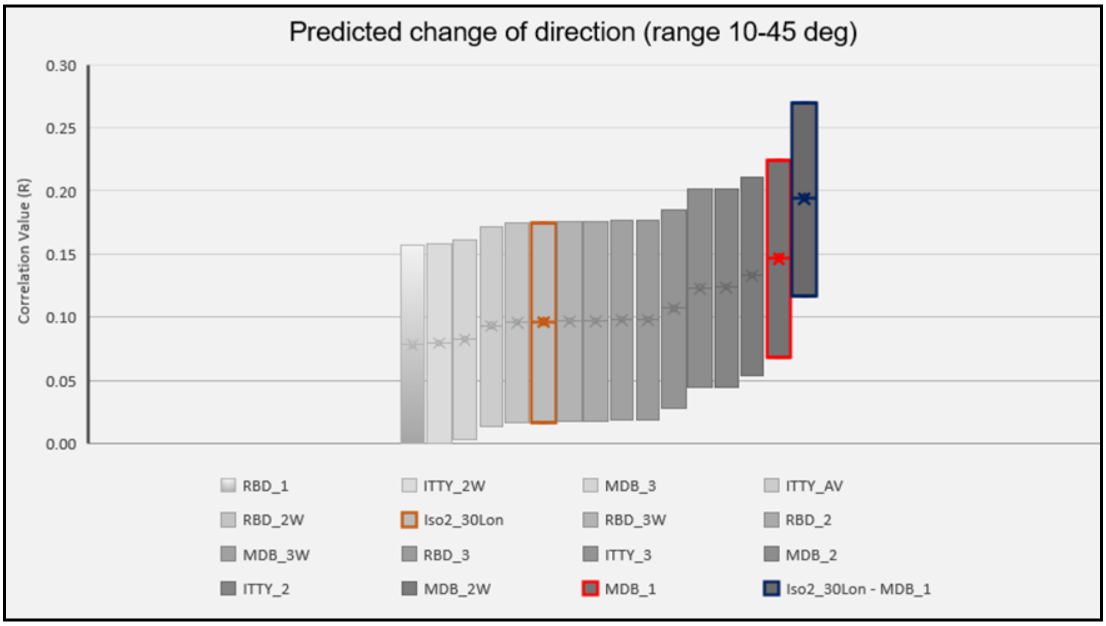

Figure 7. Absolute correlation values between the different Saliency and Isovist measures and observed data for Change of direction between 10-45 degrees. Note the Saliency results had negative correlation, but their values where flipped to be comparable with the Isovist.

Red highlights the best performing Saliency method and Orange the best performing Isovist method; Black highlights the combination of best performing Saliency and best performing Isovist method.

4. CONCLUSIONS

Our study showed that visual Saliency is correlated with observed navigational behavior. Many studies have linked saliency detection algorithms with observed eye movements and fixation (Parkhurst, Law, and Niebur 2002); this is the first study to our knowledge where Saliency detection has been applied to architecture.

In our cohort of 143 pedestrians navigating freely in an open space, we found that Saliency improved the fidelity of visibility based analysis in predicting change in direction. Specifically, we have shown a negative correlation between Saliency and navigational behaviour in a step-by-step analysis. It is yet unclear why Saliency has a negative correlation with change in direction. It could represent an avoidance behaviour by pedestrians towards salient objects, for example to avoid collision. However, there could be instances where certain salient objects act as attractors whilst others act as detractors therefore saliency models' performance could have been underestimated and could improve by determining which salient objects act as attractors and which as detractors. We have only examined cumulative effects of saliency and further research is required to assess this.

In addition, we have confirmed the importance of depth in navigation; Isovist metrics were significantly correlated with observed behavior, albeit in a constricted visual field of 30 degrees. The hallmark isovist study in Tate Gallery by Turner et al. (A. Turner and Penn 1999 ; A. Turner and Penn 2002) established correlation between isovist-based predictions and observed natural movement. Our study has confirmed that isovist measures are correlated with step-by-step navigational decisions in a larger sample of 143 pedestrians and in an open space. However the performance of isovist metrics was poorer in our cohort. This poorer performance could be due to the open-space study area, less constrained than interior spaces where isovists have previously been tested. As isovists point towards the longest ray, if there is a far destination, as long as it is within the field of view the isovist will prefer it; in contrast saliency models are more relational.

Importantly, we have shown a cumulative effect of Saliency and isovist measures; combining depth with saliency analysis led to a better performing model than each individual metric in our cohort. Saliency could represent a novel and powerful tool of spatial analysis that takes into account the visual characteristics of space and does not solely rely on spatial configuration, thus enriching existing Space Syntax based approaches.

Our study has of course certain limitations, that need to be taken into account when generalising these results. Firstly, only one building was used; this result to bias towards the dominant features of the specific architecture. Secondly, the mixture of users of the space was not recorded; their familiarity with the space or their professional background could have had affected their navigational capabilities (Hölscher, Brösamle, and Vrachliotis 2012 ; Maguire, Woollett, and Spiers 2006). Finally, their individual tasks (attending event, leaving, looking for seating) were similarly not recorded; this could have an effect to the pedestrians' navigational behaviour (Emo, 2014).

Despite these limitations, our study has demonstrated in a cohort of 143 pedestrians, that visual Saliency plays an important role with pedestrian navigation. We have recorded pedestrians in an unobtrusive, natural way, moving freely in an open space thus limiting researcher-influence in the results. Incorporating Saliency detection analysis in existing Isovist models, led to a better prediction of the observed behaviour. Saliency could be a powerful, emerging metric that could enhance the fidelity of depth-based approaches in modelling pedestrian behaviour.

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