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A Study of Co-Presence in a University Architectural Studio using Bluetooth Contact Tracing

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ABSTRACT

'Co-presence' in space syntax analysis is considered a fundamental prerequisite to various forms of social interaction (Hillier and Hanson, 1984). Spatial organisation has been found to significantly influence co-presence pattern formations (Hillier and Hanson, 1984; Hillier, 1996) and behavioural patterns (Golledge and Stimson, 1997; Sailer and McCulloh, 2012) in architecture. However, accurately identifying the precise location and duration of social interaction (and hence the building's influence) can be challenging using conventional methods such as self-reporting and observational analysis due to reliability concerns and the inability for ubiquitous observations across large spaces.

This paper investigates how non-intrusive, low-cost Bluetooth contact tracing devices (Proxxi Technology Corporation, 2022), visibility graph analysis and a post-experimental group debrief could provide practical insights on location and interaction frequency between undergraduate students at Lancaster University's new School of Architecture. These findings could prove useful to educators, researchers, and architects by showcasing the use of contact tracing technologies in academic spaces alongside "soft", adaptive, spatial solutions such as desk allocation.

The authors found that spatial configuration influenced copresence event frequency between participants in certain locations; those whose drawing boards/desks were in more integrated spaces encountered other participants more frequently. A strong negative linear correlation with 56% of the variance was also found in the number of interactions between participants, explained by the visual step depth levels between participant desk locations. Furthermore, the findings suggested a statistically significant correlation (p-value of 0.0062) in the population of pairing interactions.

KEYWORDS

co-presence, visibility, contact tracing, Bluetooth wearables, space syntax

1 INTRODUCTION

Social interaction is the bedrock of sociology and the study of human social relationships. It is through the routines of activities in everyday life that individual inhabitants can encounter each other in situated contexts that are central to forming even the most complex of social organisations (Sailer and McCulloh, 2012). However, a fundamental precondition for in-person communication is the need for at least two people to be simultaneously present in the same physical space. This least taxing – and most distinguishable – form of social interactions has been defined by Goffman (1963) as 'co- presence' whereby individuals become "accessible, available, and subject to one another" (1963, p. 22).

Furthermore, although spaces do not determine the nature of interactions, Hillier (1996) has emphasised that 'co-presence' is a clear consequence of architectural and urban design, demonstrating a strong relationship between physical spaces and social phenomena. Thus, a social entity's potential – through instances of co-presence and potential positive interactions between those co-present - are largely influenced by spatial configuration.

The primary aim of this pilot study was to explore how undergraduate students at Lancaster's new School of Architecture experienced instances of co-presence within, and outside, their designated study groups in the architectural studio. These studio spaces are where students practice design, collaborate, and engage in a collective dialogue; it is where they develop, test and present design proposals that coalesce the concepts and theories taught within the course's broader curriculum.

In creative and collaborative environments such as the architectural studio, encounters and information exchanges with other people are important aspects of the architecture culture; Schön (1992, 1987) captured the importance of such exchanges as fundamental to his concepts of 'reflection-on-action' and 'reflection-in-action'. In the former, after an activity or event, students can engage in [inter]actions which stimulate a greater understanding of that activity or event. In the latter, a student can learn to quickly develop new insights and interpretations by "respond[ing] to surprise through improvisation on the spot" (Schön, 1992, p. 11). This suggests that understanding how often people interact, who they are interacting with, and which spaces tend to facilitate these interactions could be valuable to universities and similar education providers., This paper aims to explore how instances of co-presence (captured using a discrete, Bluetooth wearable devices) relate to the integration values associated with each space in the studio, learning environment.

2 METHODOLOGY

This study used a mixed-method approach of space syntax analyses, Bluetooth tracing and focus groups to investigate the potential for co-presence during a 1-week pilot test in October 2021 at Lancaster University's new School of Architecture. The results were used to identify co-presence duration and frequency alongside spatial organisation data. To do this, the study was separated into three phases: firstly, space syntax methods, namely 'Visibility Graph Mapping' (Tahar and Brown, 2003; Turner, 2004; Lee and Lee, 2020), was used to assess spatial layouts and determine 'integration' values to predict potential areas of high co-presence based on desk configurations; the School of Architecture floorplans ('Bailrigg House') were selected for evaluation (see Fig 1). Secondly, the utilisation of Bluetooth tagging to track instances of co-presence between study participants in an unobtrusive manner within the context of the layout. Finally, the research was concluded with a post-experiment group debrief session discussing participant's experiences and their self-reports on their interactions throughout the study period.

Figure 1: Lancaster School of Architecture floorplan ('Bailrigg House'). Source Lancaster University Estates

2.1 Sample Participants

Twenty undergraduate students from the Architecture course at Lancaster University were invited to participate in this pilot study, of which five were selected (25% of the cohort). The selected participants had access, and intended, to use the studio spaces frequently for the duration of the study and all participants were second year students on the same course. The sample size of five participants was limited by the availability of the location-tracking devices. Due to the focus on simply quantifying co-presence and its relationship with space, we did not collect demographic data from participants. The pilot study was approved by the FASS-LUMS Research Ethics Committee (FASS-LUMS REC) at Lancaster University (Approval #FL20179).

2.2 Wearable Bluetooth contact tracing devices

In this pilot study, we utilised lightweight, unobtrusive wearable Bluetooth wristbands (see Fig 2) designed by 'Proxxi' Technology Corporation (Proxxi Technology Corporation, 2022) initially developed to notify employees that need to isolate for COVID. The specific use case for this Bluetooth technology in this research is to monitor the number, frequency, and duration of co-presence events between participants.

A co-presence event, for the purposes of this study, is any event that two or more sensors have been within a pre-set radius of 2 meters of each other for 30 seconds or longer. The wristbands were configured in an identify-blind way to document instances of social contact. Each wristband is assigned a unique identification number (UIN) and interacts by recording [and transmitting] signals with any other devices paired within the closed Bluetooth environment; therefore, devices do not communicate or collect data from any other non-paired Bluetooth devices outside of this closed system.

Although smartphone hardware is the most commonly used technology, it has been suggested that wearables are less obtrusive, easier for individuals to manage (Chen and Thio, 2021) and are better positioned to alleviate privacy concerns by keeping data collection away from private devices (such as mobile phones, which could be used for the same purpose) whilst providing comparable levels of accuracy (Shelby et al., 2021).

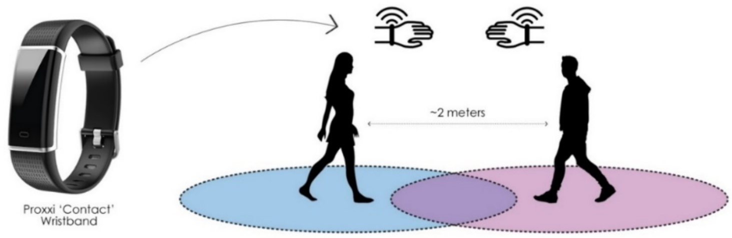

Figure 2: Proxxi BLE wristbands (left) monitoring co-presence events when within 2 m radius and 30 seconds interaction (right). Source Author

To determine a single instance of co-presence and reduce the risk of false positives, at least two-devices needed to be within a range of approximately 2m for at least 30 seconds. In previous research however it has been argued that a 20-second timeframe establishes (with 99% probability) that a face-to-face interaction has occurred (Panisson et al., 2012). All contacts between two matching devices were aggregated and included a ~3-minute cool-off threshold between interactions to prevent double counting of events. Importantly, the duration of each interaction was also recorded because, aside from number of occurrences, we assumed that continued co-presence represented a strong indicator of potential interaction. The devices stored data locally which required routine syncing with the centralised server via a software application developed by Proxxi and kindly provided for the purposes of this trial. All participants adhered with the request to wear the wristband whilst using the studio spaces and ensure their devices were fully charged every evening.

Figure 3: Proxxi 'Contact' wristband specifications. Adapted from Proxxi Technology Corporation (2022)

Product ID	Proxxi ‘Contact’
Certifications	RoHS, CE, FCC, REACH, WEEE
Connection	Bluetooth BLE 4.0
Working Time	10-12 hours (70mAh battery)
Proximity	~2 meters
Interaction Threshold Duration	~3 minutes
Accuracy	98.5%
Data Storage Memory	30 Days

2.3 Visibility Graph Analysis (VGA)

Visibility is the basic principle that the more visible people are, the more likely others will know they are present. Numerous studies since the early 1950s have shown that visibility plays several vital roles in social interaction (Sommer, 1950; Argyle and Kendon, n.d.; Steinzor, 1950). Visibility Graph Analysis (VGA) is a key space syntax method of analysing interior spaces and was chosen to analyse the eye-level visibility of the entire studio space from the location of each participant's desk (Fig. 2); specifically, we wanted to see the isovist from the view of each desk space location. 'Depthmap' software (Turner, 2004) was then used to generate an approximation to an isovist by calculating the `step depth' from the exact location of each participants desk space location. All doors, curtain walls, internal windows and furniture below eye-level were removed from the layout when applying the visibility analysis with the floor plan grid modules set to reflect the human body scale.

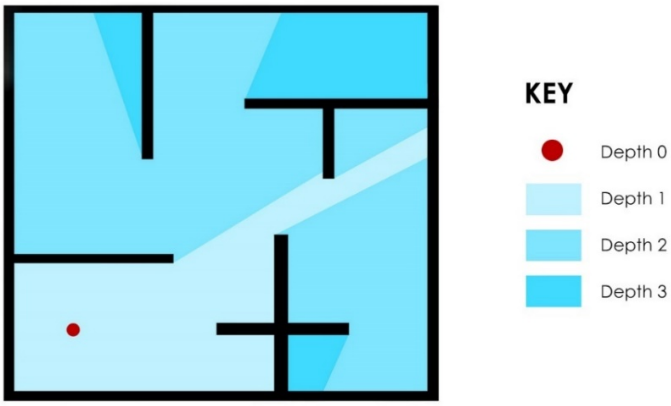

Figure 4: Example of visual depth from the starting point (depth 0) with field of view from the node equaling a depth level of '1'; the field of view from any point along the perimeter of depth level 1 equaling a depth level of '2' etc. Source Author.

The 'step depth' demonstrates the number of levels required to move from one location to another in the visibility graph; each depth represents the eye-level field of vision directly visible from each step beginning with a step depth of '0' (the starting point – see Fig 4). The field of vision from the starting point is depth level 1. Thus, depth level 2 is the extended field of vision captured from the edge of the depth level 1 perimeter, and so on. It represents the shortest route through the graph and forms a cumulative isovist from the starting point; a space with fewer step depths equates to a greater level of integration and vice-versa (Turner, 2004).

Step depth presents the depth values for a specific location within the graph; however, VGA can also be adopted to undertake an aggregated visibility analysis of a floorplan by calculating the depth values for all locations on the graph and comparing them to each other. This demonstrates the depth of a space relative to all others through the measure of `integration' value (Turner, 2004).

2.4 Post-experimental Focus Group

As an alternative to individual interviews, the authors also undertook a post-experiment, focus group (Bojlén and Lunde, 1995; Chang and Hsu, 2006) with the entire sample of five participants. This was a planned discussion conducted on the final day of the study following the collection of all the contact tracing data. The primary purpose was to collect qualitative insights from the participants regarding their interactions with the other participants during the pilot study to help evaluate and validate the results from the Bluetooth contact data analysis.

The authors met with all five participants for ~60 minutes in the studio spaces and posed open-ended questions evenly across the group to attend to different personality types a promote a balanced discussion. The questions were formulated to help gain clarity into which spaces they frequented most often, which spaces they spent most of their time occupying, why and with whom they spent most of their time throughout the duration of the study. Notes were taken on a notepad and summarised at the end of the discussion to ensure accuracy.

3 RESULTS & FINDINGS

3.1 Bluetooth wristbands

Overall, ninety-one contact interactions were identified among five participants. The data from this 1-week study showed that the highest number of interactions between participants occurred on Tuesday and Thursday; closely related to the participants' study schedule (requiring to attend in-person on these days). On Thursday, the students are required to attend a full day of Design Studio with each student having an individual tutorial (as opposed to the group tutorials on Tuesday). This should have encouraged the students to work in the studios and engage with each other more throughout the day whilst waiting for their allocated tutorial timeslot.

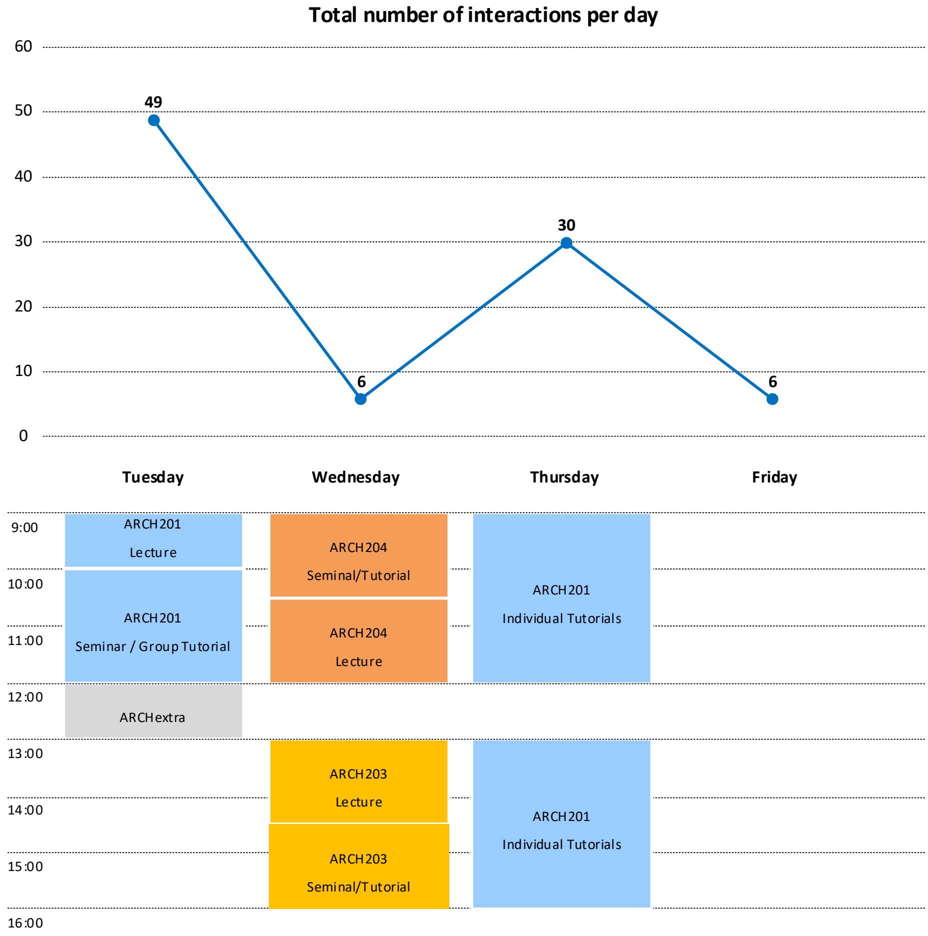

Figure 5: Total number of interactions per day (top) compared to course schedule (bottom) identifying the full day of lectures (Tuesday) and full day of individual Design Studio tutorials (Thursday) as the days with highest total interactions. Source Author

Of the five students, Participant 'A' and Participant 'B' interacted with each other the most (34 interaction events). They also happened to be allocated study spaces in the same room (B09) so were likely to have higher co-presence compared with the others. All participants who did not share a studio space with another participant registered a lower frequency of interactions. Participant 'C' who was allocated to B15 (see Fig 7), had a slightly higher number of interactions to Participant 'E' and Participant 'D', however still registered 30% less frequency of interaction than Participant 'B' and 45% less than Participant 'A'.

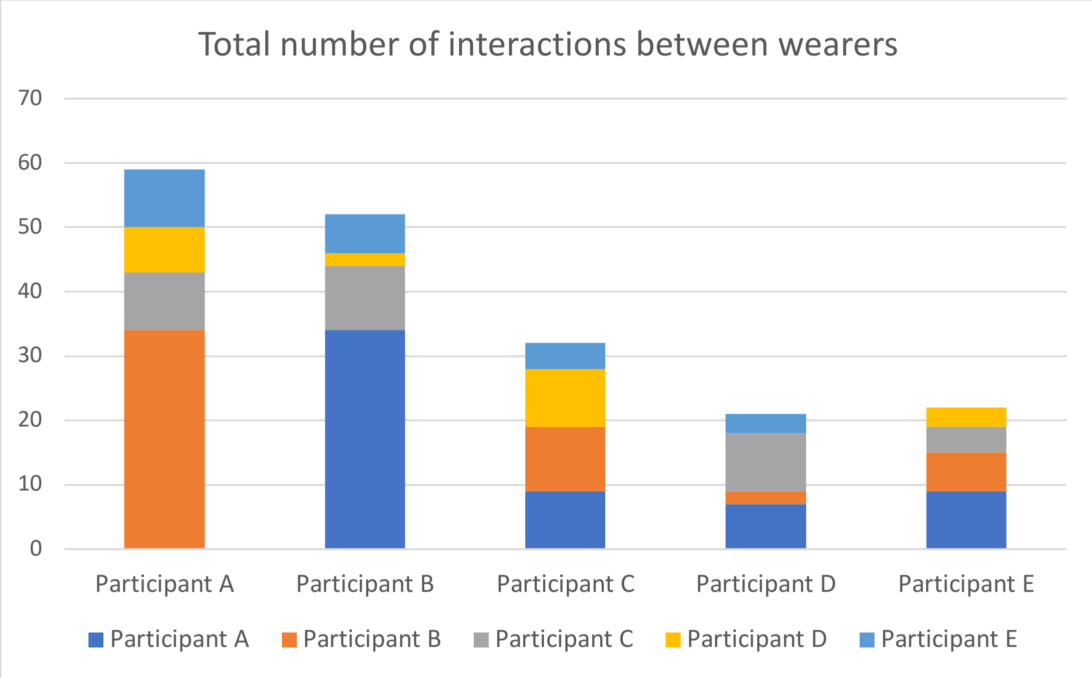

Figure 6: Total number of interactions between each participant and others. Source Author

Figure 7 below shows the exact desk location of each participant including a 2-meter radius (the approximate distance within which interactions are recorded) from the desk chair. The results show two overlapping boundaries between Participant ‘A’ / Participant ‘B’ and Participant ‘E’ / Participant ‘D’. The former overlap correlates closely with the higher frequency of interaction between the two participants. On the other hand, the latter overlap does not correlate with the frequency of interaction between the two participants, however, this can be attributed to the dividing wall between the two separate rooms. So, although there is an overlap between Participant ‘E’ / Participant ‘D’, the partition wall (and by extension separate spatial boundaries) could have influenced the lack of interaction between the two participants since the signal strength and overall range is diminished when passing through walls, although, it may not be blocked out entirely. This is exaggerated further by the fact that Participant ‘E’ and Participant ‘D’ shared the least amount of interaction between any two participants.

Figure 7: First Floor studio layout and desk allocation showing a 2-meter Bluetooth signal radius from each participant's desk chair. These signals are blocked by structural walls and weakened by partitions. Source Author

Participant 'D' (Room B01) noted they spent most of their time in their studio space but had a few interactions in the corridor spaces. They were the only participant allocated to Room B01. They also had the least interactions overall which would indicate that spatial isolation correlates with fewer interactions. Similarly, Participant 'E' was also a participant situated by themselves in their room (Room B02) and, they too, recorded the second lowest total interaction frequency. However, this participant noted they did frequent Room B09 quite often. This indicates that most of Participant 'E''s interaction may have occurred in Room 09, especially when we consider that ~75% of their interactions were with Participant 'A' and Participant 'B' who were allocated to Room B09.

This could answer why Participant 'C' (another participant who was not sharing a room (B15) with any of the other participants) interacted less frequently than the two participants sharing one studio room. It is interesting to note that, Participant 'C''s was located the furthest away from all participants yet recorded the highest frequency of interaction of the 3 participants allocated to their own spaces. This could indicate that they actively sought to interact with others spending an equal amount of time with Participant 'A', Participant 'B' and Participant 'D' (not very much time with the Participant 'E'). It should be noted that other non-participant students still use these spaces during the week so, participants could still be interacting with other non-participants during this period and are not entirely isolated.

When comparing a wearer's total duration of interactions, it became apparent this variable correlated closely with the total frequency of interactions; this is not an unexpected finding since each interaction would increase the total duration. However, we also reviewed whether the average duration per occurrence is greater in participants with a higher total frequency of interaction than those of lower total frequency. The results showed a direct positive correlation between the total duration of time spent interacting and the average time spent per interaction indicating that participants who interacted most frequently, not only spent the greatest amount of time interaction, but also spent more time in each individual interaction on average. Notably, although Participant 'A' had the spent the most time interacting with other participants, it was Participant 'B' who recorded the highest average time spent in interaction, however, the latter's total duration in interaction and total frequency of interaction monitored were very close to those of Participant 'A'.

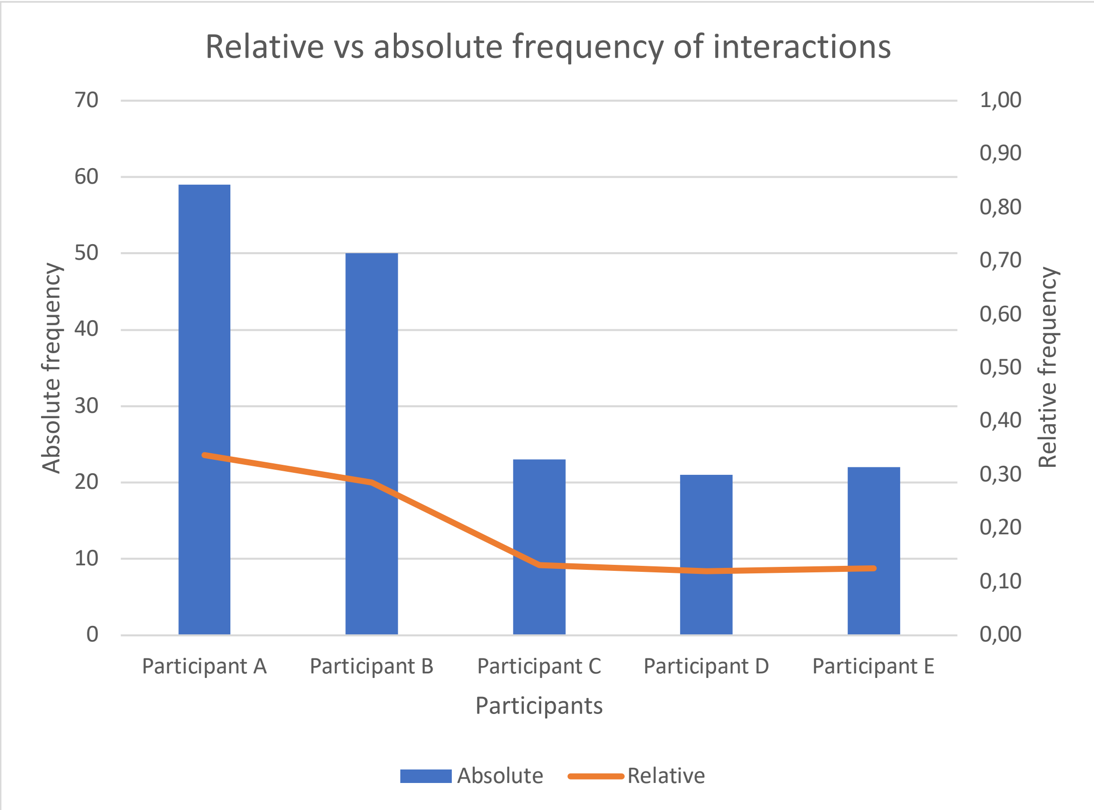

Figure 8: Relative vs absolute frequency of interactions. Source Author

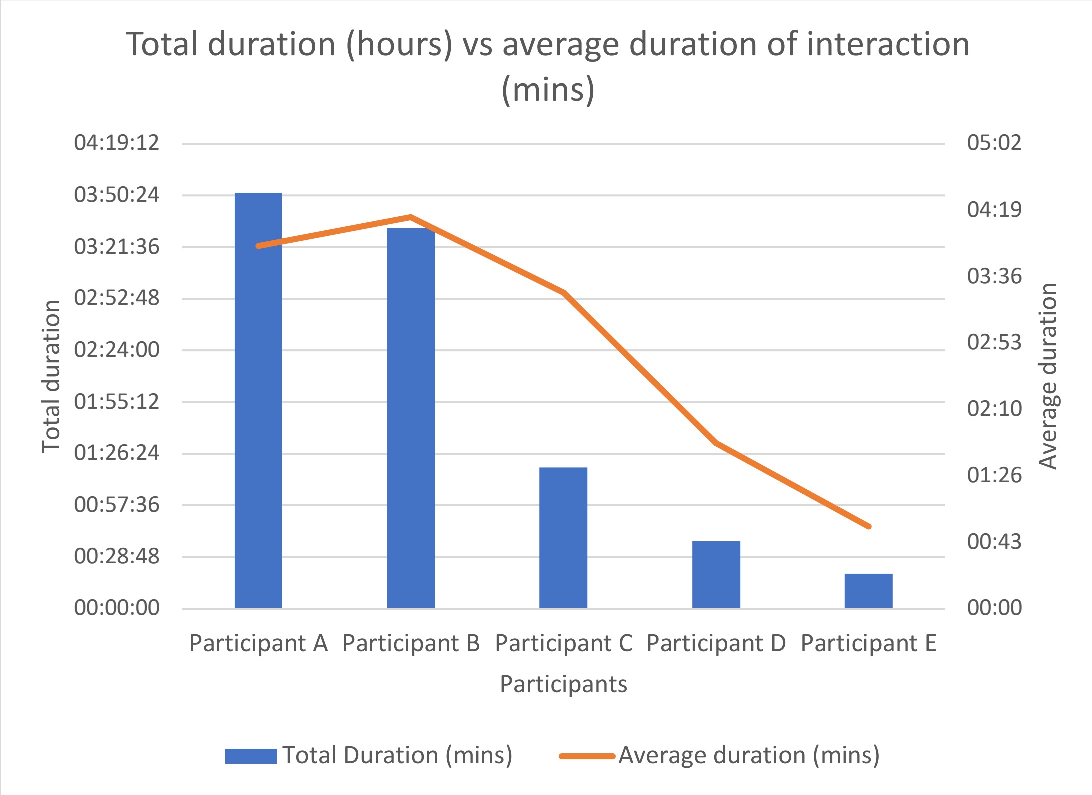

Figure 9: Total duration of interactions vs average duration of interaction. Source Author

3.2 Visibility Graph Analysis of Studio Spaces

The Visibility Graph Analysis (VGA) provided insights into the absolute correlation between total interaction time and integration value of desk space. As noted in the methodology, these step-depth maps, calculated from each of the five participants' desk locations, show the number of steps it takes for the entire floorplan to become visible at eye-level (see Fig 13-15). This approach works very well when assessing the depth values from a specific location (in this case, a participant's desk). However, for a more comprehensive and comparative depth measure analysis ('global analysis'), we first calculated the aggregated integration of the graph by calculating the step depth from all participant desk chair locations to all other locations. As identified in Fig 1, the building layout consists of a ground and first floor ('Bailrigg House); all studio spaces were entirely self-contained on the first floor (and students were not allowed access to a second floor which has therefore not been included in this analysis).

When analysing the visibility graph for the combined ground and first floors (linked via the main staircase), it became clear that the areas with the highest level of global integration were the main staircase and corridors (circulation spaces). This was a likely outcome considering the main staircase is centrally located and the primary connection between the ground and first floors; a well-integrated location requires fewer levels to get from one location to any other in the system. This analysis indicated that the staircase and corridors (and breakout space next to the staircase) are the most integrated spaces on the first-floor plan. To explore this further, we decided to undertake an isolated global integration analysis of the first floor only and found the graph closely reflected the map of the first-floor map from the dual-floor analysis of Bailrigg House, however, since there was no connection to an adjoining floor, the main staircase was no longer recognised as a highly integrated space (see Fig 11). This argument is strengthened further by the results of the step depth analysis from the top of the connecting staircase with a depth of 1 to the first-floor corridor (see Fig 12).

Since there is a clear correspondence between the integration of the corridor on both the dual-floor and single-floor integration maps, we will proceed to analyse the latter since it hosts all five participant locations, and the map contours are presented with a greater clarity.

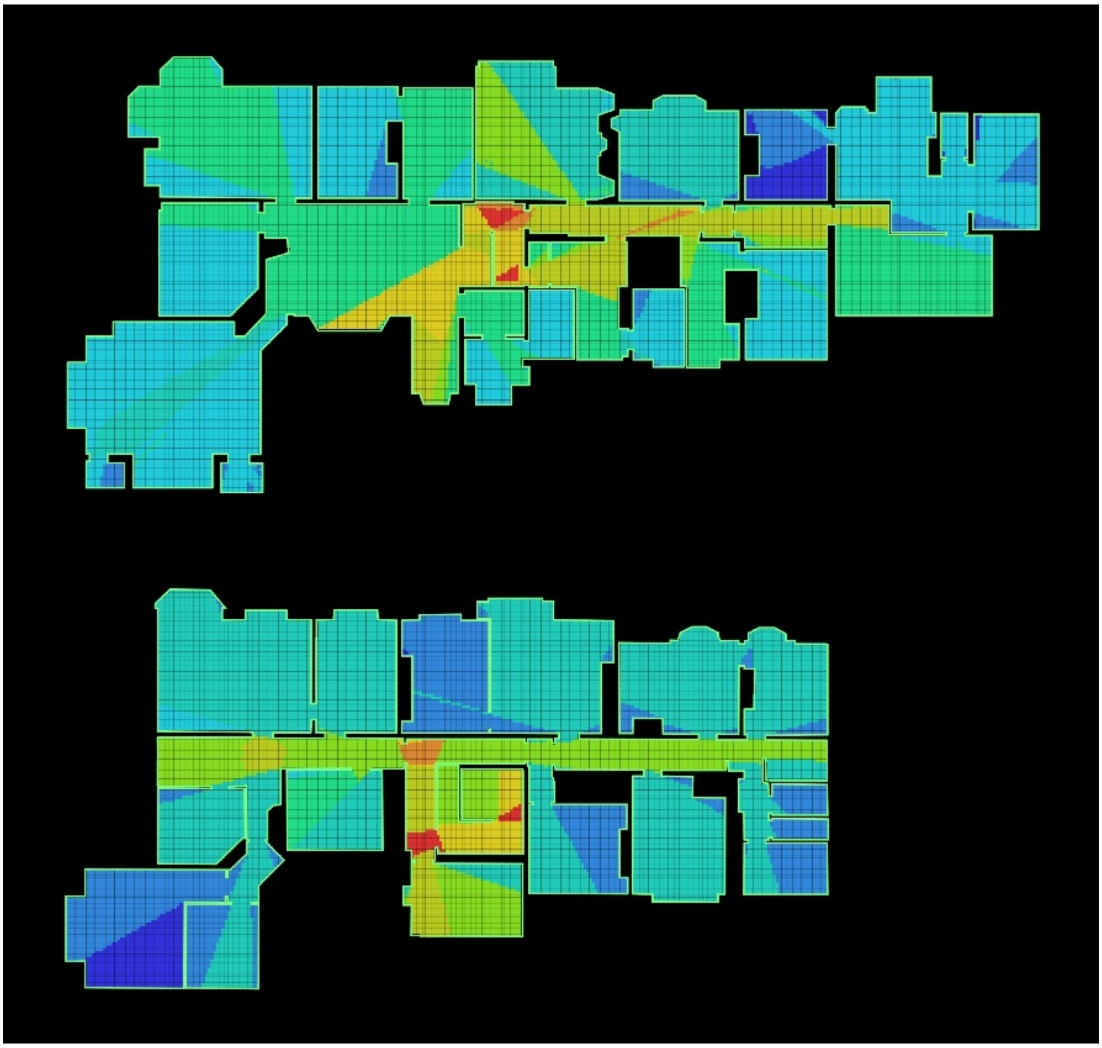

Figure 10: 'Global Integration' value of Bailrigg House including Ground (above) and first floor (below). Source Author

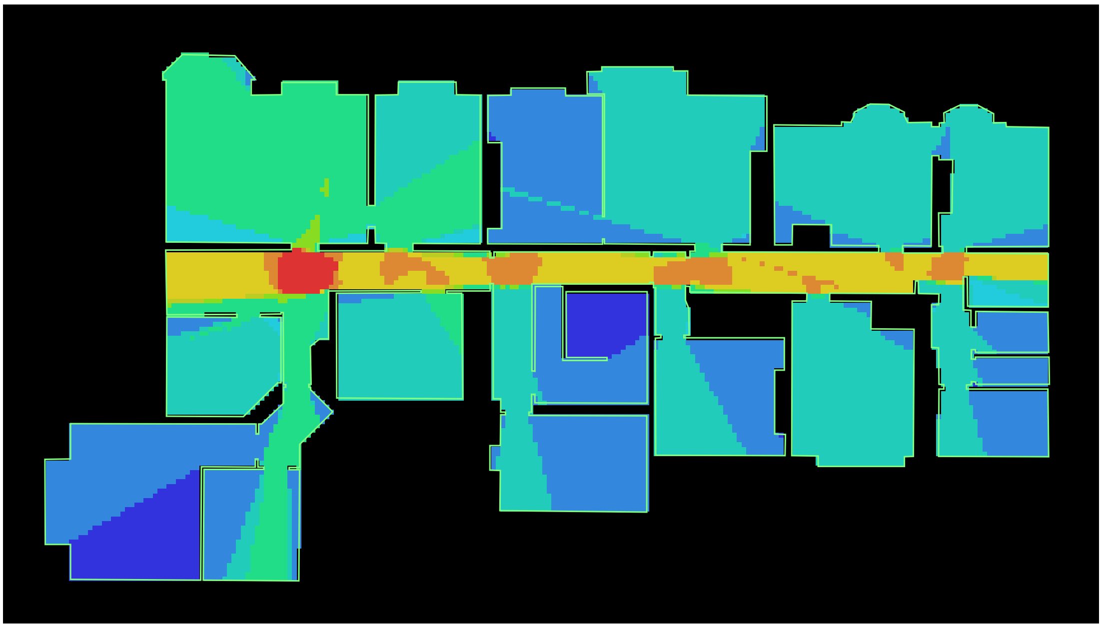

Figure 11: Global 'Integration' value of the studio spaces (first floor only). Source Author

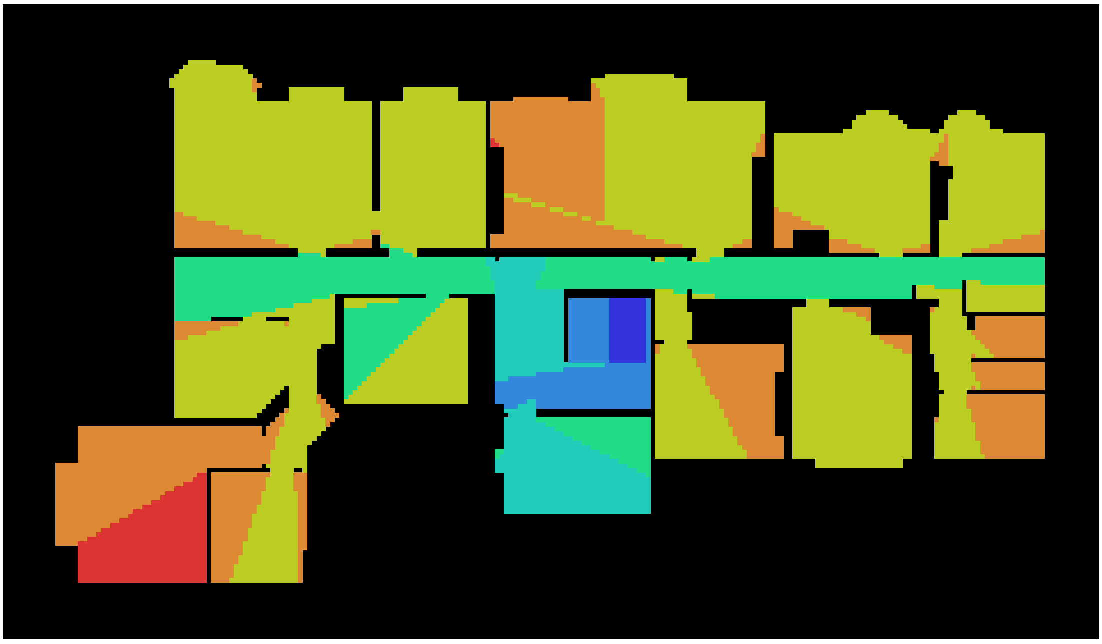

Figure 12: 'Step depth' from staircase using isolated first floor layout. Source Author

When reviewing the step depth of each participant's specific location, we noted that Participant 'A' and Participant 'B', who both share the same studio space and recorded the highest frequency of interactions, also happened to be located a Depth of '1' from the corridor. It could be suggested that the proximity of Participant 'A' and Participant 'B' to the corridor may have been influential in their potential to meet and interact with other students passing by the entrance to their studio space:

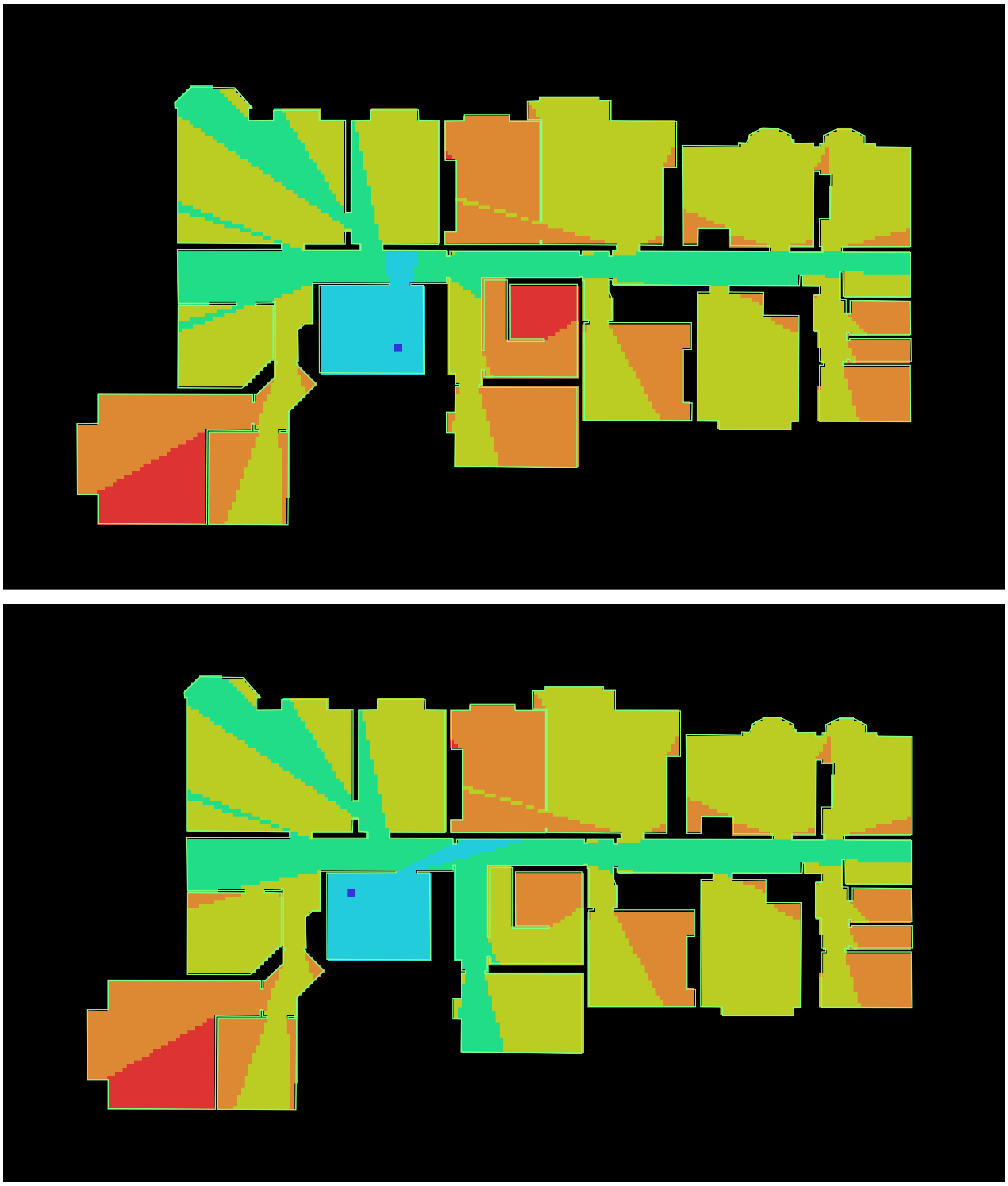

Figure 13: Desk locations and depth steps of Participant ‘A’ (above) and Participant ‘B’ (below). Source Author

Participant ‘C’, who recorded the third highest frequency of interaction, was also only a Depth of ‘1’ step from the most integrated space in the floor plan, however, the frequency of interaction may have been lower than Participant ‘A’ and Participant ‘B’ due to the fact Participant ‘C’ was the only study participant in their studio space:

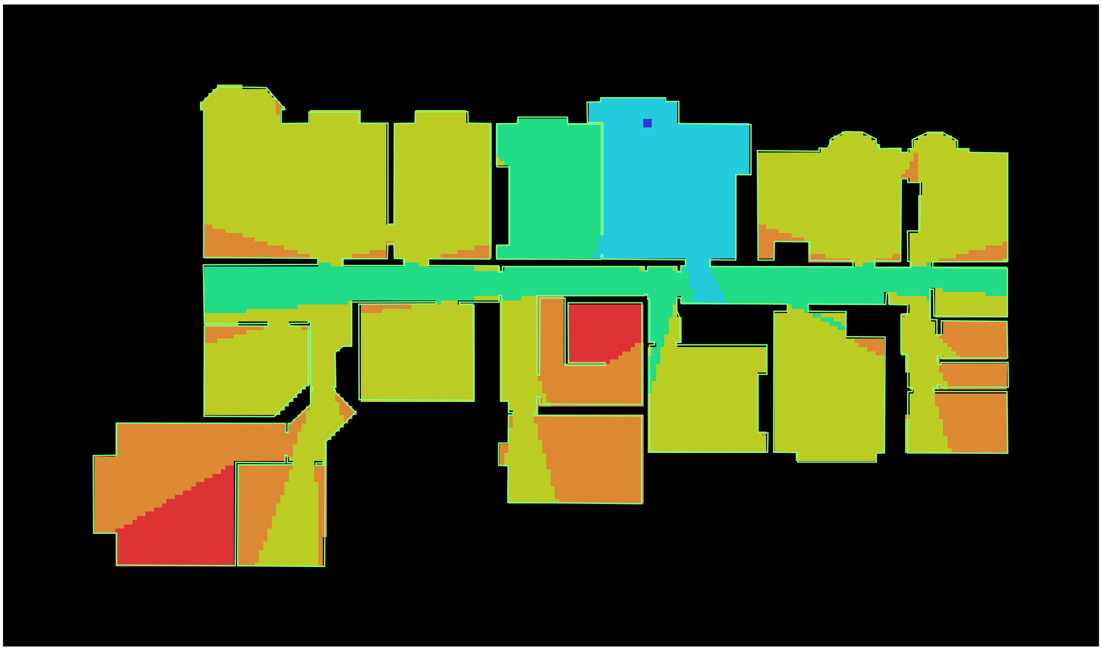

Figure 14: Desk locations and depth steps of Participant 'C'. Source Author

Participant 'E' and Participant 'D' both scored the lowest levels of overall interaction frequency; 22 and 21, respectively. Like Participant 'C', they were also the only study participants in their respective studio space. However, from the view of integration, the studio space occupied by Participant D scored a very high level of integration, so it was unexpected to see Participant 'D' as the lowest scoring participant with regards to number of interactions. Participant 'E' was in the least integrated studio space of all which correlates with the low score of 22.

Furthermore, only 3 interacts occurred between Participant 'E' and Participant 'D' (the lowest between two participants aside from Participant 'D' and Participant 'B') which is interesting considering they are only 2 depth steps away from each other:

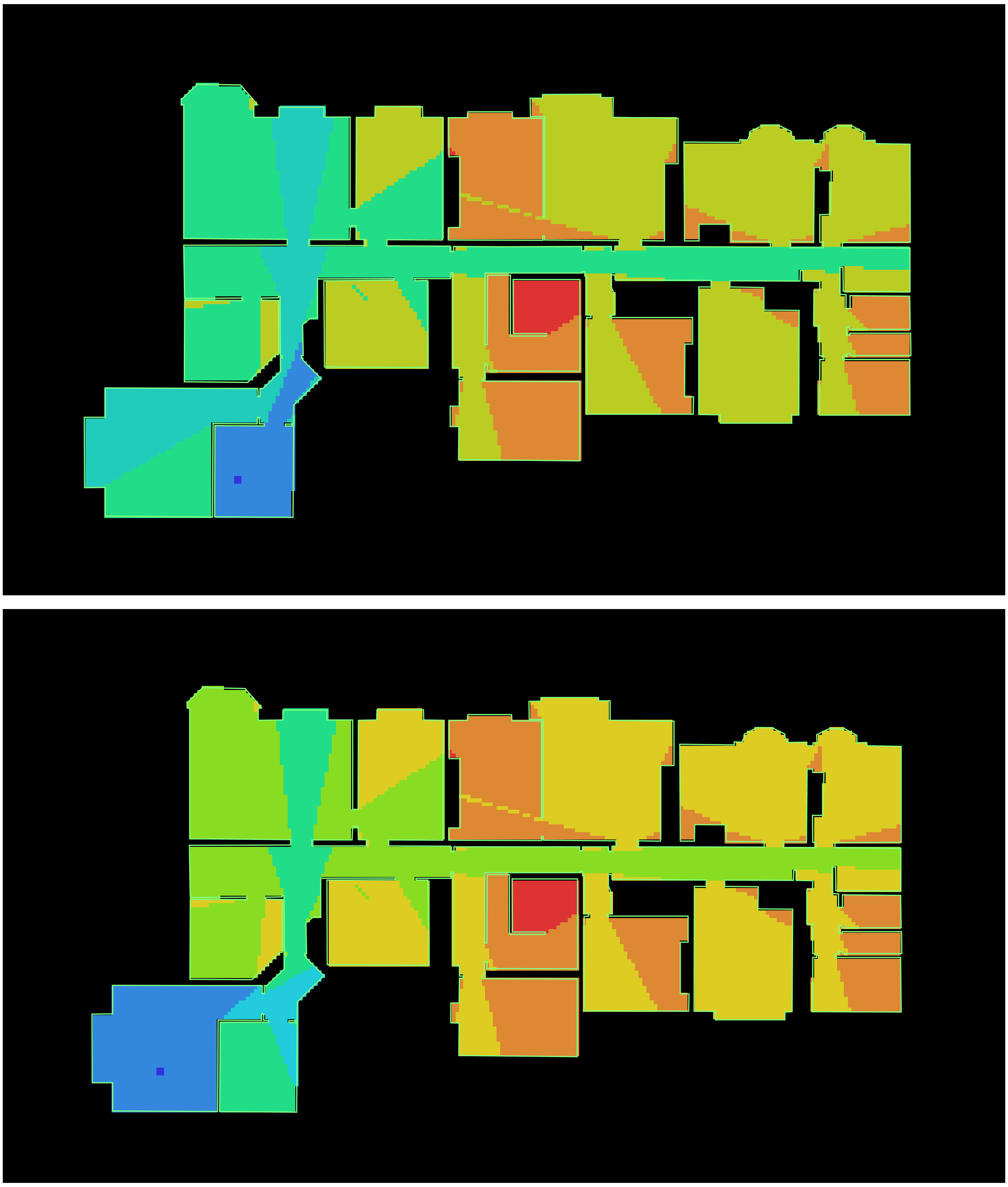

Figure 15: Desk locations and depth steps of Participant ‘D’ (above) and Participant ‘E’ (below). Source Author

We also undertook a comparative analysis of the visual step depths between each possible pair of participants’ desk locations using the global analysis to see if the absolute visual step depth between participant locations correlated with the frequency of interactions between each participant pairing. The results of the scatter plot (see Fig 16) showed a strong negative linear correlation with 56% of the variance in the number of interactions between participants being explained by visual step depth levels between each pairing’s desk locations (without considering any other variables).

We acknowledge that the participant sample size of five is small and equates to 25% of the entire population of twenty students. However, these data points (see Fig 16) relate to the number of interaction pair combinations (n) of which five participants form n=10 and twenty participants would form N=190. Therefore, we can treat the sample as independent and perform statistically significant testing to find out whether our sample is expected to be true in the population.

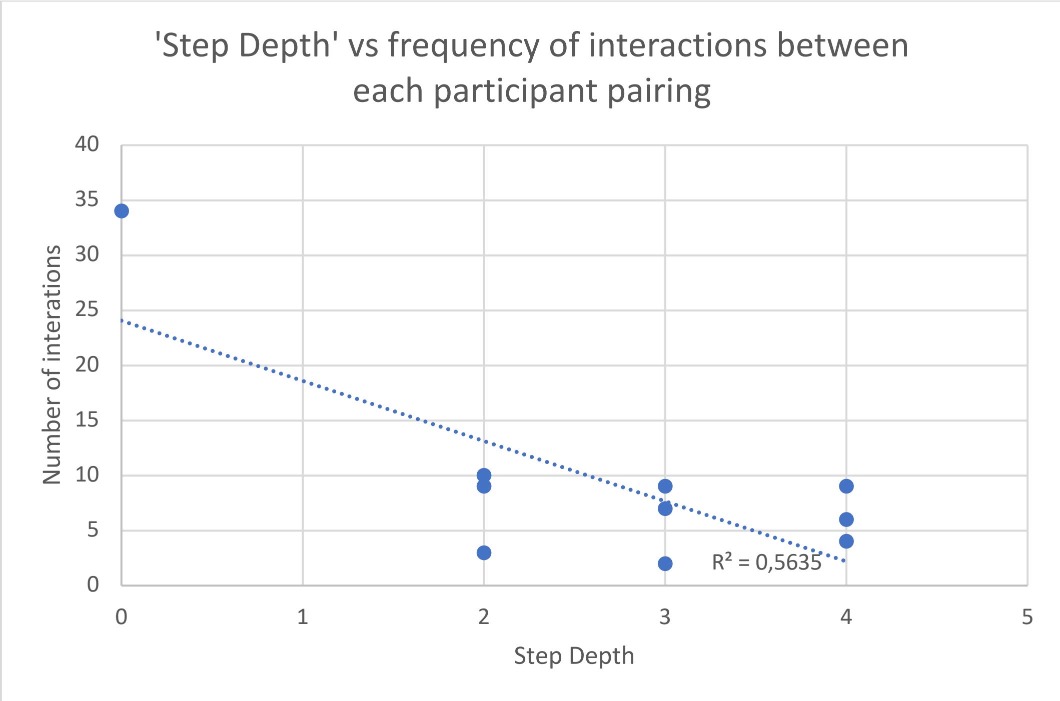

Figure 16: Scatter plot showing a negative correlation between visual step depth and frequency of interactions between participant pairings. Source Author

On this basis, we proceeded by setting out our hypothesis, where the null hypothesis is $\rho = 0$ and the alternative hypothesis is $\rho < 0$ with our significance level set to 95% ($\alpha = 0.05$). We ran a one-tailed Pearson correlation coefficient test which resulted in a p-value of 0.0062. Subsequently, we can reject the null hypothesis and suggest that the correlation is statistically significant and likely to be a negative linear relationship between step depth and frequency of interactions in the population of interaction pairings.

Notably, there is only one data point at depth 0 which has almost three times more interaction than the rest of the data set. When there is step depth other than 0, our observations suggest that the increase in step depth has a limited impact on the actual number of interactions between participant interaction pairings. The number of interactions for depth 0 are likely explained by the fact that this is the only pair of participants sharing a single space with direct visibility to each other and it is possible this data point has introduced some bias to the findings.

We also have no interactions at step depth 1, so additional data points at every depth could help reveal a more accurate prediction of the relationship between step depth and number of interactions between pairings; this will be explored further in the main study with a larger data set.

Additionally, the 'integration' value measuring the depth of each location to all others was compared against the total number of interactions for each participant. The results showed a positive correlation of r = 0.6701 and an r-squared value of 0.4491 meaning 45% of the variance in a participant's total number of interactions can be explained by their desk space integration value. However, with only 5 data points this result is not statistically significant.

4 LIMITATIONS

This research had the following limitations: firstly, the sample size was relatively small due to the limited number of wearable devices available to us during the study (however, it did constitute 25% of the cohort, which is a reasonably representative sample, although it is not independent). Following studies building on the pilot study results will aim to larger, representative samples. Secondly, the duration of the pilot study was limited to 1-week intended as a pilot study, leading to a larger implementation of the technologies/methods in a larger setting.

To strengthen the data reliability, and in addition the post-experimental focus group, we could have requested that all participants reviewed their interaction data daily (Shelby et al., 2021) rather than a one-off post-experimental debrief. Daily debriefs could have been a useful approach to validating participants' interactions before analysing the data against the visibility graph analysis. It should be acknowledged that self-assessment and self-reporting is an approach susceptible to recall bias (Shelby et al., 2021), however, if undertaken regularly, the chances of error are likely to be reduced. All these learning outcomes will be informing the current, follow-up study.

5 CONCLUSIONS

Bluetooth contact tracing technology demonstrated an effective, low-cost potential for identifying and collecting quantitative data on co-presence in university learning spaces such as an architectural studio. In combination with visibility graph analysis methods adopted from space syntax, the researchers confirmed that, although spaces do not determine the nature of interactions, 'co-presence' is a clear consequence of spatial organisation. Specifically, we have been able to support the notion that areas of higher integration are likely to correlate with higher levels of co-presence between participants.

We also found that participants studying in different spaces were less likely to cross paths or meet with participants located in less integrated spaces. This indicates that although participants do seek interactions with others stationed in different spaces, they are more likely to encounter those located in more integrated spaces. Where interactions overcame spatial separation, it was because the participants had deliberately taken actions to facilitate additional socialisation opportunities, and these appear to have been very much dependent on the personalities of the participants.

We would have liked to collect all person-to-place interaction data by placing static Bluetooth tags ('place beacons') on the walls of each space and in certain spaces, such as the kitchen, where social interactions were likely to have taken place. This would have allowed us to strengthen our stance regarding any comparison between our co-presence and step depth data whilst helping us gain a more accurate prediction of where co-presence between participants occurred most often. Due to the small sample size and short duration, we did not collect any demographical data which prevented us from evaluating whether participant personalities and personal characteristics might have acted as a variable in our results.

6 ACKNOWLEDGMENTS

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REFERENCES

Argyle, M. & Kendon, A. (n.d.) The experimental analysis of social performance. In: Berkowitz, L. (ed.) Advances in Experimental Social Psychology. London: Academic Press.

Bojlén, N.S. & Lunde, I.M. (1995) [Focus group interview as a qualitative research method]. Ugeskrift for Laeger, 157(23), 3315–3318.

Chang, M.-Y. & Hsu, L.-L. (2006) [Qualitative research: an introduction to focus group methodology and its application]. Hu Li Za Zhi The Journal of Nursing, 53(2), 67–72.

Chen, A.T.-Y. & Thio, K.W. (2021) Exploring the drivers and barriers to uptake for digital contact tracing. Social Sciences & Humanities Open, 4(1), 100212.

Goffman, E. (1963) Behavior in public places; notes on the social organization of gatherings. New York: Free Press of Glencoe.

Golledge, R.G. & Stimson, R.J. (1997) Spatial behavior: a geographic perspective.

Hillier, B. (1996) Space is the machine: a configurational theory of architecture. Cambridge, UK: Cambridge University Press.

Hillier, B. & Hanson, J. (1984) The social logic of space.

Lee, J. & Lee, H. (2020) Employing visibility and agent-based accessibility analysis to enhance social interactions in older adult care facilities. Architectural Science Review, 63(3–4), 292–302. Taylor & Francis.

Panisson, A. et al. (2012) On the Dynamics of Human Proximity for Data Diffusion in Ad-Hoc Networks. Ad Hoc Networks, 10(8), 1532–1543.

Proxxi Technology Corporation (2022) Proxxi Contact. Available at: https://www.proxxi.co/contact [Accessed: 1 January 2022].

Sailer, K. & McCulloh, I. (2012) Social networks and spatial configuration - How office layouts drive social interaction. Soc. Networks.

Schön, D.A. (1987) Educating the reflective practitioner: Toward a new design for teaching and learning in the professions. San Francisco, CA, US: Jossey-Bass.

Schön, D.A. (1992) Designing as reflective conversation with the materials of a design situation. Knowledge-Based Systems, 5(1), 3–14.

Shelby, T. et al. (2021) Pilot Evaluations of Two Bluetooth Contact Tracing Approaches on a University Campus: Mixed Methods Study. JMIR formative research, 5(10).

Sommer, B. (1950) Small group ecology. Psychological Bulletin, 67(2), 145–152.

Steinzor, B. (1950) The spatial factor in face to face discussion groups. The Journal of Abnormal and Social Psychology, 45(3), 552–555.

Tahar, B. & Brown, F. (2003) The visibility graph: An approach for the analysis of traditional domestic M'zabite spaces. In: London, Jun 17, 2003. London.

Turner, A. (2004) Depthmap 4: A Researcher's Handbook. Bartlett School of Graduate Studies, University College London: London, UK. London, UK: Bartlett School of Graduate Studies, University College London. Available at: https://discovery.ucl.ac.uk/id/eprint/2651/ [Accessed: 5 January 2022].