Evaluating the relationship between visual privacy and work-process interactions in open-plan offices: a space syntax approach

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Abstract

Purpose – Previous studies on privacy in offices have primarily focused on the characteristics of generic visibility, examining the entire visible space from each workspace in 360 degrees. Nevertheless, employees in their workspaces investigate the visual targets within their binocular vision at 120 degrees. Therefore, by adopting the affordances perspective, this study aims to examine deeply generic and targeted visibility in open-plan offices and their relationship to interactions.

Design/methodology/approach – The study consisted of two phases utilizing space syntax techniques. Initially, work-process interactions of the employees were determined through the survey. The survey data underwent spatial analysis to calculate the number of work-process interactions. Subsequently, DepthMapX software was used for visibility analyses. A new Python script for DepthMapX was developed to analyse the targeted visibility ratio. Multiple regression analyses were conducted to examine the relationship between the number of work-process interactions with generic and targeted visibility parameters.

Findings – The findings revealed that a higher number of visible employees within the 120-degree and 360-degree fields of vision corresponded to a lower number of work-process interactions in open-plan offices. Furthermore, the study establishes a direct link between visual privacy and interaction, indicating that increased visibility leads to decreased visual privacy.

Originality/value – The current research concluded that the relationship between visual privacy and interaction in open-plan offices differs from the previous studies, as employees with low visual privacy and high visibility tend to engage in fewer interactions. Overall, this study highlights that increased employee visibility is not directly associated with increased interaction in open-plan offices unless adequate visual privacy is provided.

Keywords Affordances, Open-plan offices, Privacy, Space syntax, Visibility

Paper type Research paper

1. Introduction

The layout of office environments significantly determines employees' behaviour, perceptions, and productivity (Oldham and Rotchford, 1983). Traditional office layouts are designed to accommodate enclosed private workspaces, whereas open-plan offices are formed by workplaces that lack interior walls (Zalesny and Farace, 1987). The primary objective of open-plan offices was to encourage equal participation among employees in work activities by minimizing visual barriers (Danielsson and Bodin, 2008; Sundstrom, 1986). Integrated workspaces in open-plan offices increased communication, interaction, collaboration, knowledge sharing, and creativity, leading to positively affected employees' perceptions (Boutellier *et al.*, 2008; Kim and de Dear, 2013; Yekanialibeiglou *et al.*, 2021). Open-plan offices also offer flexibility and cost-saving due to fewer walls than traditional offices (Brunia *et al.*, 2016).

Despite these advantages, uncertain divisions in open-plan offices result in some problems and negatively affect the environmental perceptions of the employees. Open-plan offices trigger low privacy, high distraction, and noise (Block and Stokes, 1989; Cangelosi and

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Lemoine, 1988). Therefore, cognitive workload increases in open-plan offices, according to De Croon *et al.* (2005), and consequently, satisfaction, productivity, and motivation reduce (Haapakangas *et al.*, 2018; Kim and de Dear, 2013; Othman and Elwazer, 2023). Furthermore, the main drawback of open-plan offices—lack of visual privacy—outweighs the advantages of increased interaction (Kim and de Dear, 2013). Therefore, this study deeply investigates the relationship between employees' visual privacy and face-to-face work-process interactions in open-plan offices.

2. Literature review

2.1 Visual privacy and visibility in open-plan offices

Numerous studies have delved deeply into privacy, regulating the interaction between the self and others and environmental stimuli (Altman, 1975; Demirbas and Demirkan, 2000; Kupritz, 1998; Newell, 1998). Privacy involves managing the exchange of information from oneself to others and from others to oneself (Margulis, 1977; Marshall, 1972). Therefore, architectural privacy, which means visual and acoustical isolation provided by the environment, directly affects psychological privacy (Sundstrom *et al.*, 1980). As visual privacy is an accidental effect of the presence of others or the activities of others, lack of visual privacy in open-plan offices negatively affects employees in terms of loss of control, satisfaction, and productivity (Brill, 1984; Patel and Angne Alfaro, 2021; Sundstrom, 1986). According to Brand and Smith (2005), employees face unwanted observation and lose personal control over their workspace in open-plan offices as privacy decreases. Furthermore, this decline in privacy diminishes satisfaction and performance and fosters negative feelings toward the workspace due to uncontrolled social contact (Maher and von Hippel, 2005). Ding (2008) also supports this notion, arguing that a loss of privacy can result in employee dissatisfaction with their current workspace. Moreover, Salama and Courtney's (2013) research on the effects of spatial qualities of the workplace on job satisfaction highlights that despite open-plan offices being prevalent in the UK, they are not the preferred choice. They demonstrate this by stating Pascoe *et al.* (2002), who found only 45% of employees indicated they would be productive in an open work environment. Furthermore, Kim and de Dear (2013) conducted a study highlighting the connection between office layout and employee satisfaction, pinpointing the lack of privacy as the primary source of dissatisfaction in offices. Despite initial satisfaction with interactions in open-plan layouts, Kim and de Dear (2013) argue that overall satisfaction diminishes over time without a maintained level of privacy. Consequently, when employees perceive their visual privacy is invaded, they actively seek to regain control over and alter their workspaces (Ding, 2008).

Employees' visual privacy is determined by the amount of enclosure and visibility in their workspaces. Visibility refers to the visual connectivity between spatial units (Bafna, 2003). Thus, when the enclosure decreases in open-plan offices, the visibility of employees increases due to higher visual connectivity between workspaces. Increased visibility leads to decreased visual privacy for employees because they cannot control the presence of other colleagues. Therefore, there is an inverse relationship between visual privacy and visibility in open-plan offices. Moreover, visibility is defined by the field of vision, which includes the range of what can be seen with the eyes. Thus, the visibility of employees in open-plan offices depends on the probability of seeing other colleagues in their field of vision (Sundstrom *et al.*, 1980). Therefore, evaluating visibility in open-plan offices becomes vital as seeing other colleagues disturbs employees while working (Fonner and Roloff, 2012; Hadi and Zimring, 2016). Previous studies related to visibility in office settings mainly focus on the characteristics of generic visibility that concentrates on all parts of space visible from each workspace rather than a specified area (Peponis *et al.*, 2007; Rashid *et al.*, 2009; Steen and Markhede, 2010). However, specific visual targets must be considered in office settings where view control and privacy issues are important because employees naturally tend to perceive and concentrate on visual information relevant to their intention.

In contrast, targeted visibility focuses on specific visual areas visible from each workspace in a setting (Lu *et al.*, 2009). The conceptual development of targeted visibility is grounded on Gibson's (1979) theory of visual perception, mainly his argument of affordances, what the environment offers the individual. Moreover, Memikoglu and Demirkan (2020) also described affordances as properties of the environment providing an opportunity to perform some action in an interior space. Thus, visibility affordance provided by open-plan offices primarily influences the interaction actions of employees (Peponis *et al.*, 2007). As each workspace has distinct fields of vision, determining the number of visible employees per workspace becomes vital to evaluating work-process interactions in open-plan offices. Therefore, workspace visibility is a significant determinant of behaviours like employees' interactions and relationships (McCoy, 2002).

2.2 Interactions in open-plan offices

Interaction naturally arises from innovative behaviour, which means generating ideas, sharing these ideas with colleagues, and implementing those ideas (Parker *et al.*, 2006; Yekanialibeiglou *et al.*, 2021). Employees must interact with their colleagues to carry out work tasks and exchange ideas (Peponis *et al.*, 2007) (Figure 1). Therefore, researchers in organizational studies have emphasized the importance of collaboration and interaction in the workplace (Katz and Kahn, 1966; Organ, 1988). In office settings, two primary types of interactions are commonly observed: social and work-process interactions. Social interactions arise from personal choices and involve informal communication. On the other hand, work-process interactions are task-oriented, focusing on completing specific tasks necessary for achieving work goals. Work-process interactions involve dedication to achieving work-related objectives (Peponis *et al.*, 2007). In this study exploring the relationship between visual privacy and work-process interactions, the focus is on physical work-process interactions involving employees' visual engagement.

Workspaces encompass two distinct concepts of relationships: social relations and sociotechnical relations (Rashid *et al.*, 2009). The social relations perspective emphasizes that the physical environment notably impacts the organizational atmosphere by shaping interactions (Oldham and Brass, 1979). Moreover, this perspective supports the idea that people interact with others when physical environments encourage interaction (Lawrence and Lorsch, 1967; Rashid *et al.*, 2009). On the contrary, from the sociotechnical perspective, physical barriers create more private and controllable work environments (Rashid *et al.*, 2009). Despite the contradiction between these concepts, Rashid *et al.* (2009) combined them by

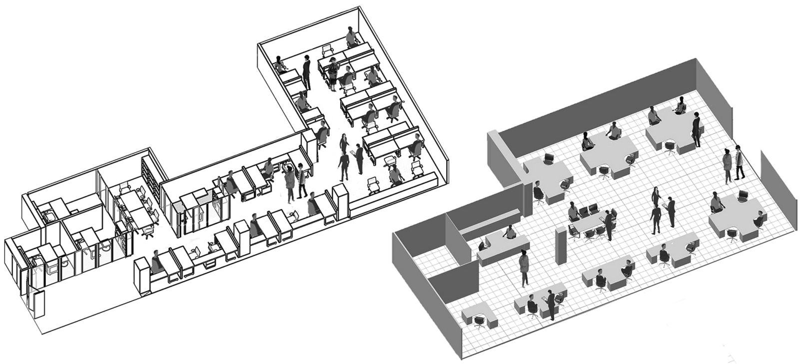

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Figure 1. Interactions in open-plan offices

proposing that open-plan offices with visible workspaces enhance employee satisfaction only when a sense of privacy is maintained. Therefore, increased employee visibility is only directly associated with increased interaction in open-plan offices if employees' visual privacy is provided (Kim and de Dear, 2013). Thus, this study employs the space syntax technique to investigate the relationship between visual privacy and work-process interactions in open-plan offices through visibility analysis.

2.3 Space syntax methodology

Space syntax is a method used to analyse the relationship between employees' behaviours and the spatial configuration of open-plan offices (Peponis *et al.*, 2007; Rashid *et al.*, 2009). This approach also helps to identify visibility patterns within work environments (Hong and Yoo, 2010; Steen and Markhede, 2010). Space syntax methodology analyses spatial configurations on an architectural plan by assigning values that indicate the level of social activity (Aknar and Atun, 2017). Hillier and Hanson developed this methodology at the University College London (UCL) in the late 1970s to early 1980s by proposing that the spatial properties of buildings are translated into sociological rules (Hillier and Hanson, 1984). Therefore, there is a strong relationship between spatial layout and user behaviour (Penn, 2005). This study explores the relationship between visual privacy and work-process interactions using different space syntax techniques as follows:

(1) Linear integration map

Integration impacts the density of interaction across a layout (Grajewski, 1993). Therefore, linear integration maps through spatial analysis are used to measure interactions in offices for this study. This technique involves representing the layout using intersecting lines (Hillier and Hanson, 1984; Turner *et al.*, 2005). The objective is to draw the fewest and longest circulation lines as well as lines connecting each workspace. The level of connectivity of these drawn lines is determined by the number of intersections they have with other lines (Peponis *et al.*, 2007).

(2) Generic visibility analysis

Generic visibility analysis concentrates on all parts of space visible from each location in a setting (Lu *et al.*, 2009). In this study, visual integration through Visibility Graph Analysis (VGA), degree, and density parameters are investigated within the framework of generic visibility analysis. Visibility graph analysis evaluates the characteristics of mutually visible locations in a spatial layout (Turner *et al.*, 2001). Visual integration levels obtained through visibility graphs measure the visual distance from all spaces to all others (Hillier, 2007). This parameter calculates visibility by overlapping all visible spaces from each location to all others (Turner and Penn, 1999). Thus, the visual integration results indicate inter-visibility by combining both the visibility of others and being visible to others. DepthMapX calculates the intervisibility of points; however, these points are not shown due to a high number of points. Instead, the points are coloured according to their visibility levels (Pinelo and Turner, 2010).

Moreover, according to social network analysis, the degree of a node refers to the number of nodes adjacent to it (Wasserman and Faust, 1994). Borrowing this definition, Sailer *et al.* (2021) defined degree as the number of people with whom someone is directly connected. In this study's context, degree indicates the number of directly visible employees sitting from a specified workspace within the 360° isovists (Figure 2). In addition, density means the number of people per square metre, calculating the ratio of degree to 360° isovist area (Sailer *et al.*, 2021).

(3) Targeted visibility analysis

Targeted visibility analysis examines visual targets and the number of targets visible from various locations in a setting (Lu *et al.*, 2009). Through targeted visibility analysis, this study investigates outdegree, binocular density, and targeted visibility ratio (TVR) parameters.

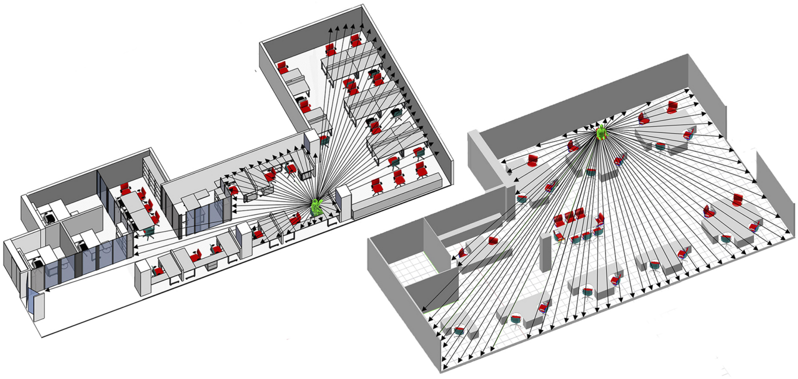

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Figure 2. Generic visibility (360° vision) in open-plan offices

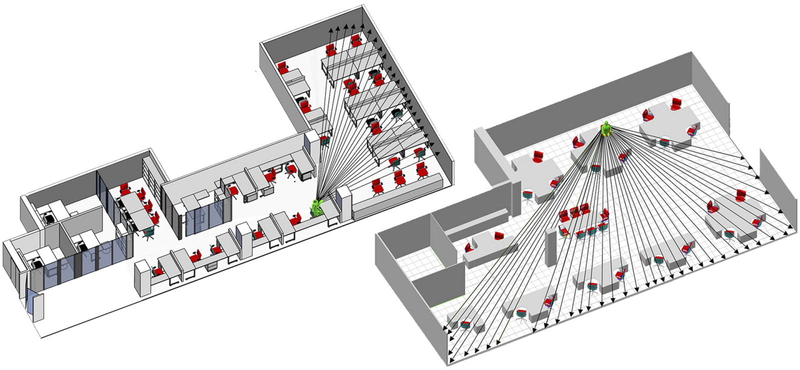

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Figure 3. Targeted visibility (120° vision) in open-plan offices

Outdegree quantifies the number of workspaces directly visible to someone with binocular vision limits (Sailer *et al.*, 2021). In this study's context, outdegree indicates the number of directly visible employees sitting within the 120° forward-facing isovist (Figure 3). Moreover, binocular density indicates the number of people per square metre, calculating the ratio of outdegree to 120° isovist area (Sailer *et al.*, 2021).

Additionally, TVR measures the ratio of the number of visible employees (sitting or moving) in the 120° isovist area at two distinct distances: personal (60 cm.) and social (150 cm.). This examination aims to discern whether varying distances have an impact on TVRs. The selection of these two distances is rooted in Hall's (1966) description of interpersonal distances and is particularly relevant to the study's context of office environments. Personal distance aligns with interactions among familiar people like colleagues and friends, whereas social distance belongs to more formal and impersonal relationships, such as business conversations (Cristani *et al.*, 2013).

3. The current study

Based on the literature review, previous studies on employees' visual privacy, visibility, and interactions have some limitations. First, few studies emphasizing targeted visibility analysis mainly deal with hospitals or museums (Peponis *et al.*, 2004; Lu, 2010), where analysis of work environments is scarce (exception: Markhede and Koch, 2007). Second, studies focusing on visual privacy that use a computational analysis approach are rare (Alkhazmi and Esin, 2017; Khozaei Ravari *et al.*, 2022). Third, few studies have developed a tool to measure targeted visibility (Lu, 2010). Last, the relationship between employees' visual privacy and interaction is not studied deeply.

This study mainly focuses on the association of visual privacy with workspace interactions in open-plan offices through generic and targeted visibility analyses. Moreover, the study explores how generic and targeted visibility parameters correlate with the number of work-process interactions in open-plan offices. Therefore, the study is developed to find an answer to the following questions:

RQ1. How does generic visibility affect work-process interactions?

RQ2. How does targeted visibility affect work-process interactions?

Based on previous research studies, degree, density, and visual integration are found to be the fundamental parameters to measure generic visibility (Hillier, 2007; Sailer *et al.*, 2021). Besides, outdegree, binocular density, and TVR are mainly used parameters to measure targeted visibility (Sailer *et al.*, 2021; Wasserman and Faust, 1994). Thus, the following hypotheses are proposed related to generic and targeted visibility parameters, respectively:

H1. Degree is negatively correlated with the number of work-process interactions.

H2. Density is negatively correlated with the number of work-process interactions.

H3. Visual integration is positively correlated with the number of work-process interactions.

H4. Outdegree is negatively correlated with the number of work-process interactions.

H5. Binocular density is negatively correlated with the number of work-process interactions.

H6. TVR is negatively correlated with the number of work-process interactions.

H6a. TVR at a personal distance is negatively correlated with the number of work-process interactions.

H6b. TVR at a social distance is negatively correlated with the number of work-process interactions.

4. Methodology

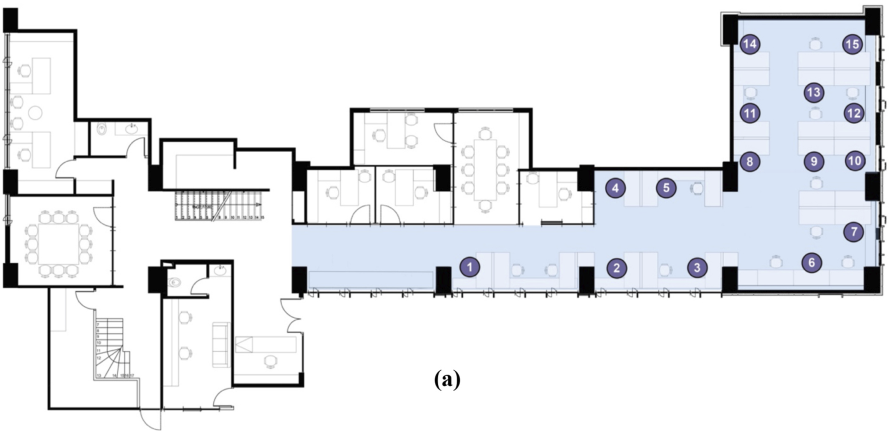
4.1 Participants

The participants are the knowledge workers of two open-planned design offices in Ankara, Turkey. Thirty employees were involved in the study (16 females and 14 males). All participants ages ranged from 22 to 50, with a mean age of 32.20 years (SD = 8.36). There were an equal number of participants from each open-plan office. Among 15 participants of Office A, 11 were female, and four were male, with a mean age of 29.27 (SD = 7.28) years. Among 15 participants of Office B, five were female, and ten were male, with a mean age of 35.13 (SD = 8.57) years. The age range of the participants was from 22 to 49 in Office A and from 24 to 50 years in Office B. Participants of both offices were the members of a design team practicing the design profession either as an architect, interior architect, or drafting technician. Workspaces in open-plan offices were assigned to employees by their administrators in each office. Participants were seated knowledge workers facing their computers, and visibility analyses were carried out according to this working posture. All participants were non-administrative employees at the same hierarchical level. Participation was on voluntary basis, and the study was reviewed and approved by the Ethics Committee of I.D. Bilkent University (Approval No. 2021_11_23_01), and all participants provided the written informed consent form.

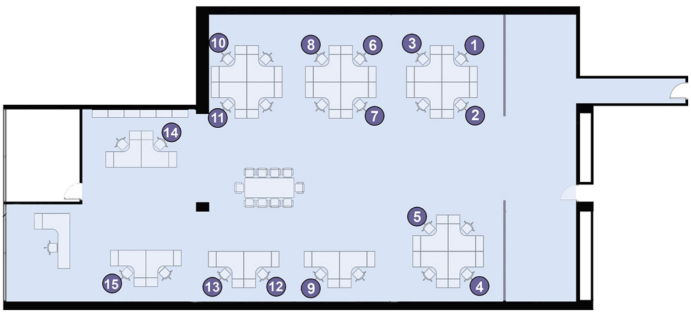
4.2 Settings

The study was conducted in two open-plan offices in Ankara, Turkey. These offices were selected as settings for this study because of their open-plan layout and the work type they performed, both being architectural design firms. In these open-plan offices, employees have individual workstations assigned by their administrators working in private offices. Therefore, all employees working in the open-plan part of the office hold non-administrative roles and are at the same hierarchical level.

Office A is located in a 3-story building in a residential complex. The open office space of A is on the ground floor, which allocates 139.95 m^2 of the total 325 m^2, as seen in Figure 4a. In



(a)



(b)

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Figure 4. Floor plans of two open-plan offices (shown in blue) of the study: (a) Office A, (b) Office B (not to scale)

addition to open office space, the ground floor includes five private offices and two meeting rooms. Only two building facades have windows, allowing almost half of the employees to access natural light and ventilation. On the other hand, Office B is located on a university campus. The open office space of B is on the first floor of the building. The total first-floor area is 1,194 m^2, and the open office space allocates 301 m^2, as seen in Figure 4b. Besides the open office space, private offices and three meeting rooms are on this floor. Only one facade of the open office space has windows, resulting in limited access to natural light and ventilation for all but one employee.

4.3 Measures of the study

4.3.1 Survey. Work-process interactions in open-plan offices are determined through a survey. The survey consisted of two sections with open-ended questions. The first section of the survey focused on gathering demographic data; age, gender, and occupation. The subsequent section is designed to identify patterns of work-process interactions within open-plan offices. Each workspace was assigned a number from one to 15 on the office floor plan to develop the linear integration maps. Firstly, the workspace number of the participant was indicated on the open-plan office. Then, the participant was asked to indicate the workspace number of the most interacted colleague, determined by the highest number of interactions in the last year. The data collected through the survey were transferred to DepthMapX software for spatial analysis. According to the responses provided by participants in the survey, indicated workspaces were connected through lines, and these connections were assessed based on their levels of connectivity.

4.3.2 DepthMapX software. Work-process interactions, generic, and targeted visibility were analysed using DepthMapX software, a specialized space syntax software that identifies and evaluates spaces to understand social processes in the built environment (Aknar and Atun, 2017). In 1998, Alasdair Turner developed this software from the Space Syntax group at the University College of London as DepthMap, the first given name. It provides spatial analyses through integration and visibility calculations by placing thousands of isovists representing a volume of visible space from a particular workspace (Aknar and Atun, 2017; Turner and Penn, 1999). The topological analysis of the given spaces is achieved by juxtaposing isovist graphs.

4.3.3 Targeted visibility analysis tool (TAVAT). TVR was calculated using Targeted Visibility Analysis Tool (TAVAT), a new script developed for DepthMapX. The first author developed the codes in Python using PyCharm, an integrated development environment used in computer programming for Python language. TAVAT was developed to determine the visual targets (other employees walking or sitting) visible from each workspace in the open-plan offices. It was developed using isovists, visible areas from a particular point.

TVR is calculated by TAVAT in three stages:

Stage I – Firstly, the specific targets, other employees walking around and sitting, were determined for each participant. For each workspace in the open-plan offices, isovist analyses were carried out individually, and visible areas for each desk were defined (Figure 5a). During partial isovist analysis, calculations of isovists were performed while employees were facing their computers. Only isovists with a binocular vision limit (120°) were considered (Diffrient *et al.*, 1974).

Stage II – The total number of grids in the specified isovist area was calculated (Figure 5b). The default grid size set by DepthMapX according to the dimensions of the open plan of each office was used (see Figure 4).

Stage III – Lastly, the number of visible employees for the defined isovist area was calculated at two distinct distances: personal (60 cm.) and social (150 cm.) (Figure 5c).

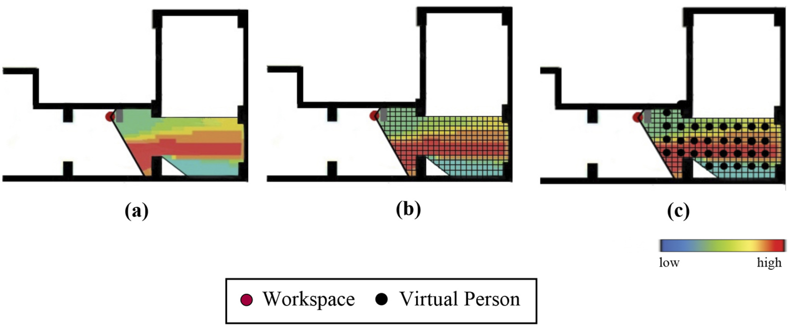

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Figure 5. Three stages of the targeted visibility tool of Office A for one workspace: (a) Stage I, (b) Stage II, (c) Stage III

These distances determine how far virtual people apart within the defined isovist area. Virtual people represent other employees who sat, worked, and walked inside the isovist area. TVR was calculated by the ratio of the number of visible employees in the isovist area to the number of grids in that area.

4.4 Procedure

The study was conducted in two phases (Figure 6). In the first phase, with the survey, the work-process interactions of the employees were determined. On the given layout, participants were first asked to indicate their workspaces. Then, they identified the workspace of an employee with whom they interacted the most for work processes in the last year. The survey data were transferred to DepthMapX software for spatial analysis. Based on participants' survey

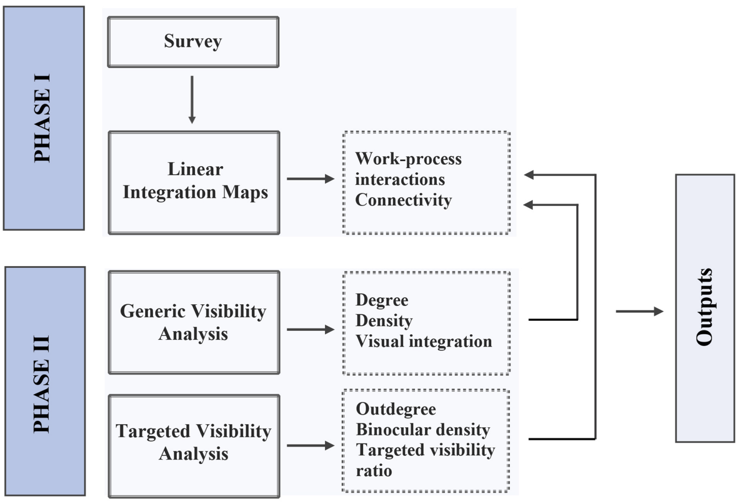

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Figure 6. Framework of the study

responses, lines connecting their workspaces to those of their most interacted colleagues were drawn to create a linear integration map. Connectivity values, representing the number of intersections of each line, were obtained to determine the number of work-process interactions in open-plan offices. In the second phase, visibility analyses were performed through DepthMapX software. Firstly, generic visibility analysis is performed to obtain visual integration, density, and degree values. Secondly, targeted visibility is analysed to calculate outdegree and binocular density values. Then, TVR was calculated through TAVAT. The outputs of the first and second phases were analysed through linear integration maps, generic and targeted visibility analyses to understand the relationship between visual privacy and the number of work-process interactions in open-plan offices.

5. Results

5.1 Work-process interactions

Spatial analysis was conducted using DepthMapX software to calculate the number of work-process interactions. First, responses from the first section of the survey were used to understand the demographic characteristics of two open-plan offices, including age, gender, and occupation (see Supplementary material for demographic data). Then, participants' responses from the second section of the survey were used to identify work-process interactions in open-plan offices. Lines were drawn connecting respondents' workspaces to those of the colleagues they interacted with most. These lines were then used to create a linear integration map. As seen in Figures 7 and 8, linear integration maps were obtained for two open-plan offices using connectivity values representing the number of other lines intersected by each line. The colour change from blue to red represents low to high interactions, respectively (Peponis *et al.*, 2007). Moreover, thicker lines indicate higher interactions. In addition to graphical representations, numerical connectivity values are determined, as shown in Table 1. The table's first column (Workspace Number) indicates each respondent's workspace number. The last column represents connectivity levels, indicating the number of intersections of each line. The mean connectivity value of Office A is 7.55 (SD = 1.76), while the mean connectivity value of Office B is 2.85 (SD = 1.23).

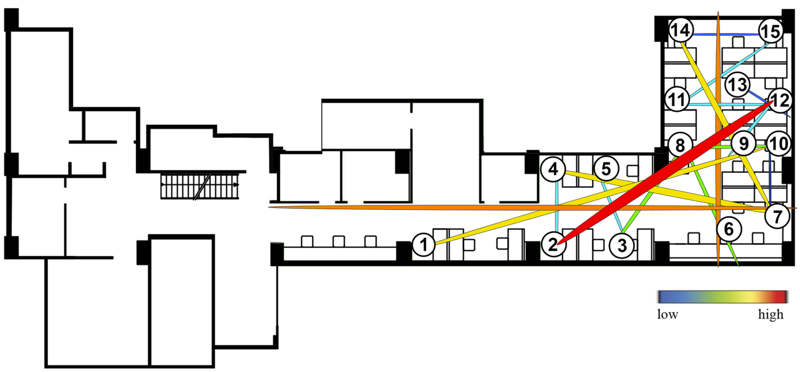

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Figure 7. Linear integration map of Office A (not to scale) (connectivity values range from 5.00 to 12.00)

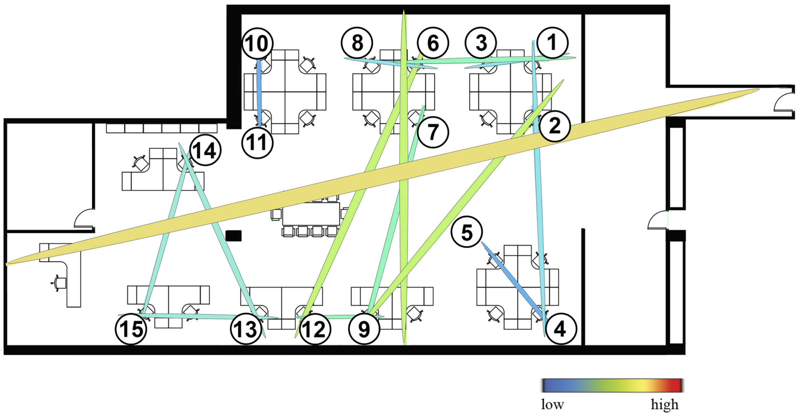

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Figure 8. Linear integration map of Office B (not to scale) (connectivity values range from 1.00. to 4.66)

Table 1. Connectivity values of Office A and B

Workspace numbers	Connectivity Office A	Office B
1	12.00	3.33
2	10.00	4.66
3	7.50	2.00
4	8.00	2.50
5	7.00	1.00
6	8.00	4.00
7	7.66	4.00
8	7.66	3.00
9	6.50	4.33
10	7.50	1.00
11	6.00	1.00
12	8.00	4.00
13	5.00	2.50
14	7.50	3.00
15	5.00	2.50

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5.2 Generic visibility

Visual integration levels are obtained by analysing visibility graphs (see Figure 9a and 9b). In order to measure degree, as seen in Figure 9c and 9d, visible employees were represented with green circles within the 360° isovists of a specified workspace, indicated with a yellow square. Additionally, for density, the 360° isovist areas were obtained for each workplace in the office. Then, density was calculated by the ratio of visible employees within the 360° isovist to the area of the isovist. As seen in Figure 9e and 9f, the red shaded area represents the area of the 360° isovist of the specified workspace indicated with a yellow square. Visible employees within the 360° isovists were indicated with green circles (Figure 9e and 9f).

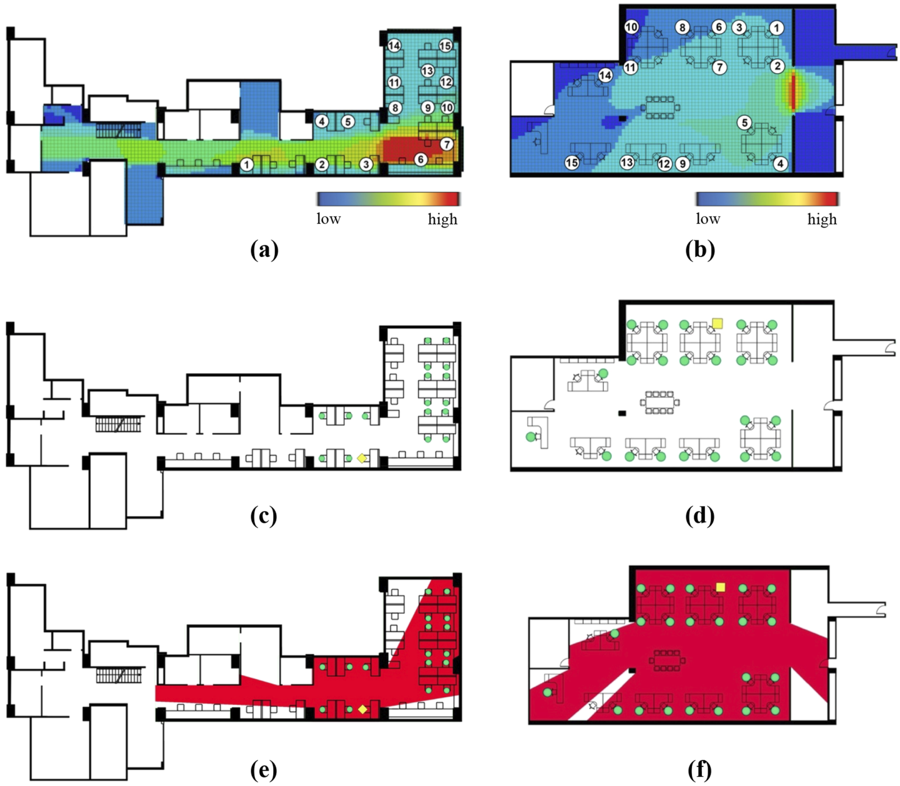

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Figure 9. Generic visibility analysis parameters illustrated for a sample desk from both Office A and B, respectively: (a and b): Visual Integration, (c and d): Degree, (e and f): Density

Values obtained through generic visibility analysis of two open-plan offices were analysed according to degree, density, and visual integration parameters. The mean degree value of Office B (M = 23.07, SD = 1.28) is higher than Office A (M = 17.53, SD = 5.32). Fluctuations in the degree values of two open-plan offices are similar except in workspaces from 1 to 5 in Office A, which were located in the small wing of the L-shaped plan layout of Office A (see Figure 1). The rest of the building had a more compact floor plate with a rectangular layout like Office B. However, the mean density values of Office A (M = 0.18, SD = 0.04) is higher than Office B (M = 0.07, SD = 0.003). The density values of the two open-plan offices are explicitly different since the density values of the workspaces of Office B do not differ from one to another due to the compact floor plan. Although there are fluctuations in the visual integration levels of both offices, Office B (M = 59.50, SD = 14.36) is visually more integrated than Office A (M = 14.04, SD = 6.05).

5.3 Targeted visibility

In order to measure outdegree, as seen in Figure 10a and 10b, visible employees were represented with green circles within the 120° isovist of a specified workspace, indicated with a yellow square. Moreover, for binocular density, isovist areas for each workspace were calculated while employees faced forward as seen in Figure 10c and 10d. Following the partial

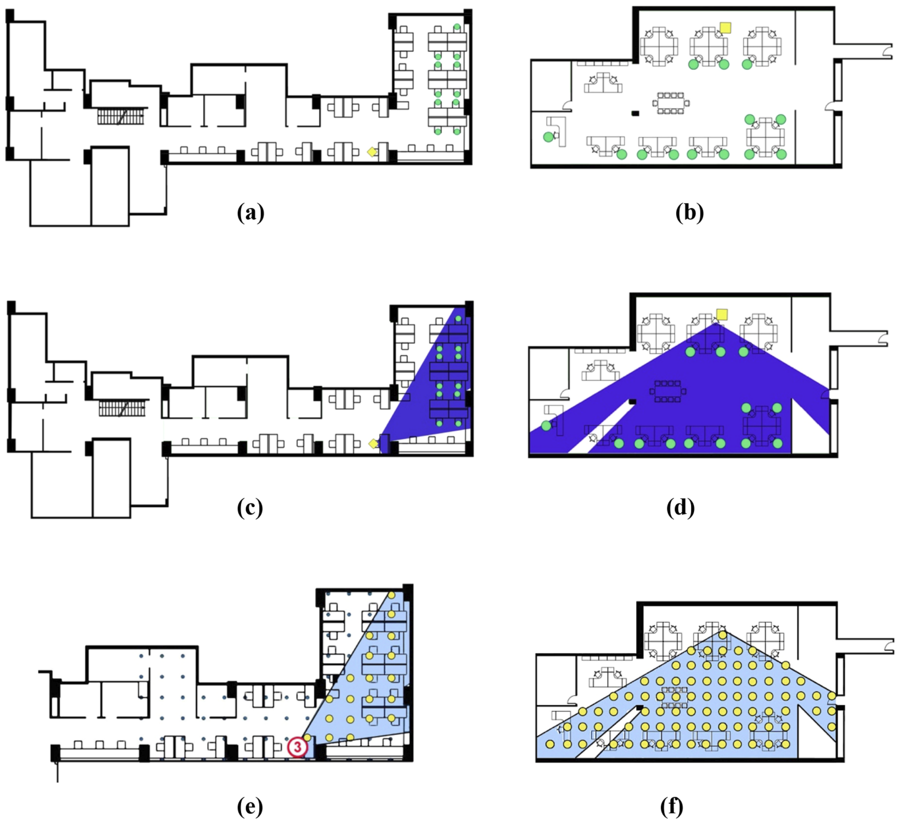

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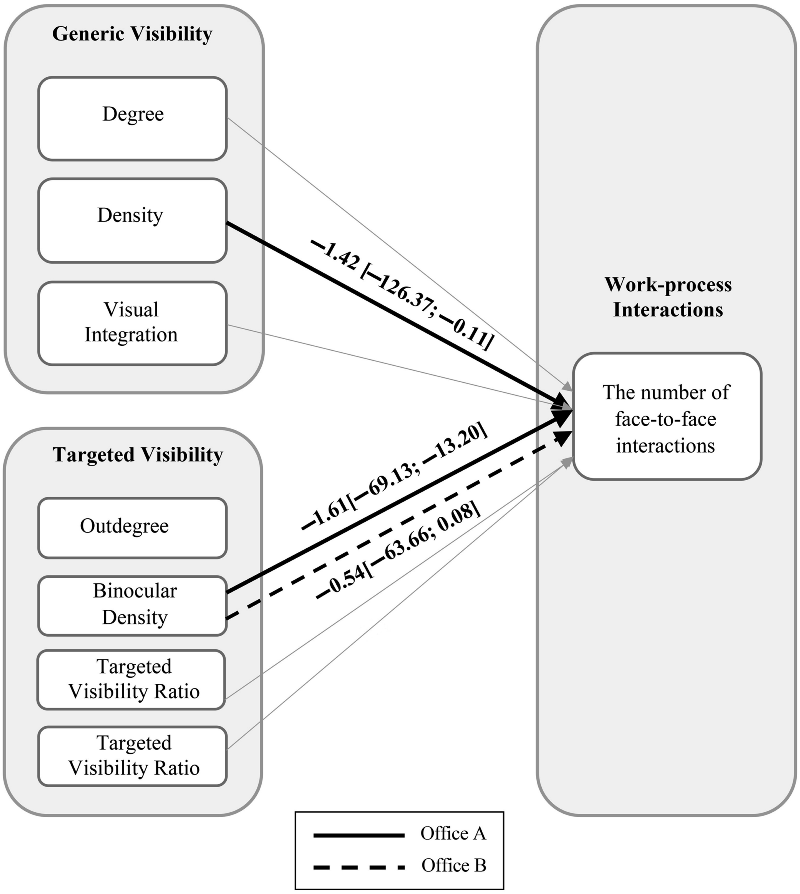
Figure 10. Targeted visibility analysis parameters illustrated for a sample desk from both Office A and B, respectively: (a and b): Outdegree, (c and d): Binocular density, (e and f): TVR (150 cm.)

isovist analysis, areas of the 120° isovist were obtained. Then, binocular density was calculated by the ratio of visible employees within the 120° isovist to the area of the isovist. As seen in Figure 10c and 10d, the purple shaded area represents the area of the 120° isovist of the specified workspace indicated with a yellow square and visible employees within the 120° isovists were indicated with green circles (Figure 10c and 10d). As seen in Figure 10e and 10f, the TVR of visible employees were indicated with yellow circles within 120° isovist represented with the blue shaded area.

Values obtained through targeted visibility analysis of two open-plan offices were analysed according to outdegree, binocular density, TVR-personal distance, and TVR-social distance parameters. The mean outdegree value of Office B ($M = 9.53$, $SD = 4.69$) is higher than Office A ($M = 8.67$, $SD = 4.48$). On the other hand, the mean binocular density value of Office A ($M = 0.19$, $SD = 0.07$) is higher than Office B ($M = 0.07$, $SD = 0.02$). Moreover, the mean TVR (personal distance) of Office B ($M = 0.25$, $SD = 0.01$) is higher than Office A ($M = 0.24$, $SD = 0.07$). The mean TVR (social distance) of Office A ($M = 0.04$, $SD = 0.01$) is the same as Office B ($M = 0.04$, $SD = 0.003$).

5.4 Regression analyses

Multiple regression analyses were conducted to analyse the relationship between the number of work-process interactions with generic and targeted visibility parameters (see Supplementary material for relevant statistics). According to the regression analysis of Office A, density was negatively correlated with work-process interactions (β = −1.42, SE = 28.68, p < 0.05, [−126.37, −0.11]). Moreover, binocular density was negatively correlated with work-process interactions (β = −1.61, SE = 12.55, p < 0.008, [−69.13, −13.20]). In office A, work-process interactions were determined by the generic visibility density parameter and the targeted visibility binocular density parameter. On the other hand, in Office B, only binocular density was negatively correlated with work-process interactions (β = −0.54, SE = 14.30, p < 0.05, [−63.66, 0.08]). Figure 11 represents the summary of the regression coefficient analyses.



Source(s): Created by the authors

Figure 11. Generic and targeted visibility parameters and their relation to the number of work-process interactions

6. Discussion

Findings are discussed according to the hypotheses related to the generic and targeted visibility parameters.

H1 posits that degree is negatively correlated with the number of work-process interactions. According to the regression analysis results, there was no significant relationship between degree and the number of work-process interactions in Office A and B. In other words, an increased number of employees within the 360° isovist area (higher degree) did not affect the number of work-process interactions in open-plan offices. The rejection of H1 could originate from the different spatial properties of the two offices. According to Hillier *et al.* (1986), the spatial layout of a setting could affect the number of interactions in the setting. Interactions could increase in settings with the integrated plan layouts (Hillier and Grajewski, 1990; Toker and Gray, 2008). In other words, the spatial properties of an office could determine the level of the interactions. Office B had a more integrated plan layout with its visual integration value when compared to Office A, which had a fragmented plan layout. Moreover, the degree values of the two open-plan offices were very similar when workspaces 1 to 5 in Office A were excluded. These five workspaces were located in the small wing of the L-shaped plan layout of this office. The rest of the setting had a more compact floor plate with a rectangular layout like Office B. Therefore, differences in degree values resulted from the different plan layouts of two open-plan offices and caused an insignificant relationship between degree and work process interactions.

H2 posits that density is negatively correlated with the number of work-process interactions. Regression analyses showed that a higher ratio of visible employees to the area of the 360° isovist (higher density) resulted in fewer work-process interactions in Office A. On the other hand, there was no significant relationship between density and the number of work-process interactions in Office B. The density values of the two open-plan offices were explicitly different because density values in Office B did not change from one workspace to another as a result of the compact floor plan. Differences in density values could be originated from the different plan shapes of the two offices. Office A had a more fragmented floor plate with a wing shape layout (L shape) while Office B had a more compact floor plate with a rectangle layout. According to Shpuza and Peponis (2008), offices were highly integrated when they had floor plans with low fragmentation, like compact blocks. In contrast, offices were poorly integrated when their floor plans had high fragmentation, like wing shapes (L, F, and U shapes). Therefore, with its compact floor, Office B was more integrated than Office A, which had a fragmented wing shape layout. Moreover, because of the highly integrated plan layout, the density values in Office B were the same for 14 employees out of 15. As density values did not change from one workspace to another, no relationship was found between density and the number of work-process interactions in Office B. Therefore, the findings of Office A supported our assumptions about the density of open-plan offices. H2 positing that density is negatively correlated with the number of work-process interactions was supported.

H3 posits that visual integration is positively correlated with the number of work-process interactions. According to the regression analysis, there was no significant relationship between visual integration and the number of work-process interactions in open-plan offices. In other words, visually more connected workspaces (with higher visual interaction values) were not where a high amount of interaction occurred. H3 was rejected because of insignificance. The results contradict the findings of Hillier and Grajewski (1990) that a higher degree of employee interaction occurred in more integrated office settings. Also, Sailer *et al.*'s (2016) study found that more integrated offices support higher levels of interaction. These contradictions with the findings of the studies were probably based on the usage of different Space Syntax measurements in DepthmapX software to measure integration (Axial Analysis for the study of Hillier and Grajewski (1990), mean depth for the study of Sailer *et al.* (2016), and visual integration for this study). On the other hand, this study's results were similar to Steen and Markhede's (2010) study, which used space syntax methods (Visibility Graph Analysis) to analyse the relationship between spatial and social configurations in offices. This study's findings aligned with Steen and Markhede's (2010) study, which found no correlation between integration values and interactions in open-plan offices.

H4 posits that outdegree is negatively correlated with the number of work-process interactions. According to the regression analysis, there was no significant relationship between outdegree values and the number of work-process interactions in both open-plan offices. In other words, the increased number of visible employees within the field of vision at 120° did not decrease the number of work-process interactions in both open-plan offices. H4 was rejected because of insignificance. Previous literature on the field of employees' visions only analysed the effects of fields of vision on employees' preferences in open-plan offices. A study by Sailer *et al.* (2021) suggested that employees with a limited field of vision (lower outdegree) evaluated their workspaces better regarding productivity. On the other hand, Alavi *et al.* (2018) found that employees willing to interact socially in open-plan offices preferred workspaces with higher outdegree.

H5 posits that binocular density is negatively correlated with the number of work-process interactions. Regression analysis of Office A showed that binocular density was negatively correlated with work-process interactions. Moreover, regression analysis of Office B also proved that binocular density was negatively correlated with work-process interactions. In other words, regression analyses showed that a higher ratio of visible employees to the area of the 120° isovist (higher binocular density) resulted in lower numbers of work-process interactions in the open-plan office. This study's results were similar to Bernstein and Turban's (2018) study, which found that increased visibility in open-plan offices causes reduced face-to-face interaction. Therefore, employees preferred different communication tools to face-to-face interaction in open-plan offices. H5 suggesting that binocular density is negatively correlated with the number of work-process interactions was supported.

H6 posits that TVR is negatively correlated with the number of work-process interactions. To the best of the authors' knowledge, TVR has not been presented in the literature before.

H6a posits that TVR at a personal distance is negatively correlated with the number of work-process interactions. The regression analysis showed no significant relationship between the TVR at a personal distance and the number of work-process interactions in both open-plan offices. In other words, while facing forward at the workspace, seeing more employees walking and sitting at a personal distance did not affect the number of work-process interactions in both offices. H6a was rejected because of insignificance.

H6b posits that TVR at a social distance was negatively correlated with the number of work-process interactions. According to the regression analysis, there was no significant relationship between TVR at a social distance and the number of work-process interactions in open-plan offices. In other words, while facing forward at the workspace, seeing more employees walking and sitting at a social distance did not affect the number of work-process interactions in both offices. H6b was rejected because of insignificance.

7. Conclusion

7.1 Theoretical contribution

The study's findings contribute to workplace environment research in the following two ways, providing a deeper understanding of the relationship between visual privacy and work-process interactions in open-plan offices.

First, the layout of open-plan offices significantly affects visibility and interaction levels. Offices with a compact layout, such as square and rectangular shapes, are more integrated than offices with a fragmented layout like wing shapes L, F, and U. Thus, the findings of this study claim that different spatial layouts cause differences in visibility levels. Each workspace has similar targeted and generic visibility values in open-plan offices with a compact plan layout. On the other hand, targeted and generic visibility values are different in open-plan offices with more fragmented layouts. Moreover, according to the findings of this study, a higher number of work-process interactions occurred in the office with a fragmented L-shaped layout compared to the office with a compact rectangular layout. This difference is attributed to low visual privacy and high visibility in open-plan offices with a compact layout, causing employees to avoid interactions. Therefore, according to this study's findings, open-plan offices with compact floor plates facilitate fewer work-process interactions due to reduced visual privacy. In other words, visually connected open-plan office layouts with compact floor plans do not promote many work-process interactions. In contrast, open-plan offices with fragmented layouts like wing shapes promote more work-process interactions as they provide a higher level of visual privacy.

Second, the main conclusion is that more visible employees within 120-degree and 360-degree fields of vision corresponded to fewer work-process interactions in open-plan offices. Employees' field of vision refers to the entire area visible to them while working in open-plan offices. Therefore, employees' visibility, the probability of seeing other colleagues in the office, is determined by the field of vision of each employee, which encompasses the areas they can see while working. According to the results of this study, the visibility of employees, influenced by what they can see when facing forward (with a 120-degree field of vision) and when looking all around (with a 360-degree field of vision), affects the number of work-process interactions. Overall, the results of the current research demonstrated that among all parameters of generic and targeted visibility, density values for 120 and 360° isovists are determinant factors for the number of work-process interactions. Therefore, more visible employees per unit in 120 and 360° isovist areas mean fewer work-process interactions in open-plan offices. A conclusion is drawn that employees avoid interactions when the ratio of visible employees to the area of their fields of vision increases in open-plan offices. As increased generic and targeted visibility mean decreased visual privacy, there is a direct relationship between visual privacy and work-process interactions, according to the findings of this study. In other words, when employees have workspaces with low visual privacy or high visibility, they avoid interactions with their colleagues. All in all, according to the results of this study, increased employee visibility is not directly associated with increased interaction in open-plan offices unless employees' visual privacy is provided.

7.2 Implications for practice

Architects and interior designers must consider employees' visibility and interaction while designing offices, especially open-plan ones. Initially, ensuring similar visibility for employees from the same hierarchical level is recommended in open-plan offices. However, varied visibility levels for different employees are acceptable to highlight hierarchical differences. Additionally, arranging workspaces to avoid direct employee visibility is crucial for enhancing interaction and preserving visual privacy. Therefore, adjusting the orientation of workspaces can help to find an optimal field of vision with minimal exposure to colleagues. Spatial analysis tools can aid in measuring the field of vision of each employee during furniture layout design. Last, fragmented open-plan layouts with L, F, and U shapes can be preferable over compact open-plan floor layouts like rectangular shapes to enhance visual privacy, resulting in increased work-process interactions.

7.3 Limitations and future research

The current study has some limitations. First, the study was conducted with two small-scale design companies during the COVID-19 pandemic. It was challenging to get permission for the study and conduct it in a larger company at that time. Therefore, small sample sizes are used for this study. Future studies are recommended to investigate the relationship between visual privacy and interaction in large-scale open-plan offices to increase the validity of this study's findings. Second, all respondents of this study were members of a design team practicing the design profession. However, various occupations have different needs and preferences regarding visual privacy, visibility, and interaction. Therefore, further studies on visual privacy and interaction in open-plan offices could concentrate on employees who are non-designers to see whether the findings of this study are generalizable to different line employees. Thirdly, this study considers movement by measuring the visibility of employees sitting and moving through TVR. However, movement significantly impacts visibility in interior spaces. Therefore, it is recommended that future studies on visibility focus on the effects of movement on employee visibility in open-plan offices. Moreover, as a medium of interaction, the study focuses on physical work-process interactions to understand their relationship with visual privacy. It is important to note that digital and verbal interactions also impact physical interactions in both positive and negative ways. Thus, it is suggested that future studies on work-process interactions encompass a comprehensive analysis of the interaction's physical, verbal, and digital components. Lastly, the evaluation of work-process interactions is primarily based on the number of interactions in this study. However, the length and content of the interaction also play a significant role in evaluating the interaction. It is recommended that future studies delve into the potential impact of these parameters when measuring interactions.

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Table A1. Raw data – Office A

Workspace no.	Degree	Density	Visual integration	Outdegree	Binocular density	TVR-personal distance	TVR-social distance	Connectivity
1	8.00	0.09	18.00	6.00	0.09	0.248	0.040	12.00
2	11.00	0.14	17.32	9.00	0.16	0.249	0.035	10.00
3	17.00	0.15	20.63	11.00	0.21	0.255	0.035	7.50
4	10.00	0.15	9.00	8.00	0.16	0.253	0.031	8.00
5	12.00	0.17	9.81	3.00	0.16	0.252	0.034	7.00
6	21.00	0.15	26.28	0.00	0.00	0.000	0.000	8.00
7	27.00	0.19	25.71	14.00	0.26	0.252	0.040	7.66
8	18.00	0.21	9.84	8.00	0.23	0.256	0.043	7.66
9	22.00	0.21	12.11	9.00	0.24	0.259	0.041	6.50
10	24.00	0.21	12.88	8.00	0.23	0.252	0.042	7.50
11	18.00	0.22	9.44	9.00	0.22	0.251	0.037	6.00
12	20.00	0.21	10.19	11.00	0.2	0.234	0.031	8.00
13	19.00	0.22	9.96	3.00	0.18	0.278	0.050	5.00
14	17.00	0.21	9.49	15.00	0.24	0.250	0.037	7.50
15	19.00	0.22	9.87	16.00	0.24	0.240	0.033	5.00

Source(s): Created by the authors

Table A2. Raw data – Office B

Workspace no.	Degree	Density	Visual integration	Outdegree	Binocular density	TVR-personal distance	TVR-social distance	Connectivity
1	24.00	0.07	57.17	12.00	0.06	0.244	0.035	3.33
2	24.00	0.07	70.32	2.00	0.06	0.254	0.033	4.66
3	24.00	0.07	58.13	12.00	0.06	0.244	0.036	2.00
4	24.00	0.07	69.93	14.00	0.08	0.260	0.039	2.50
5	24.00	0.07	86.54	3.00	0.13	0.227	0.029	1.00
6	22.00	0.07	55.17	13.00	0.06	0.248	0.037	4.00
7	24.00	0.07	58.86	3.00	0.08	0.254	0.035	4.00
8	23.00	0.07	51.78	14.00	0.06	0.246	0.037	3.00
9	23.00	0.07	71.65	13.00	0.06	0.250	0.038	4.33
10	20.00	0.08	29.52	11.00	0.07	0.240	0.036	1.00
11	24.00	0.07	51.92	3.00	0.11	0.218	0.033	1.00
12	23.00	0.07	69.68	13.00	0.07	0.256	0.040	4.00
13	24.00	0.07	72.75	14.00	0.07	0.246	0.038	2.50
14	22.00	0.07	42.25	6.00	0.06	0.236	0.033	3.00
15	21.00	0.07	46.79	10.00	0.08	0.255	0.037	2.50

Source(s): Created by the authors

Table A3. Regression analysis – Office A

	β	*p*	95% CI	R^2
	Connectivity			0.71
Degree	0.53	0.368	[−0.24; 0.59]	
Density	−1.42	0.050	[−126.37;−0.11]	
Visual Integration	−0.46	0.375	[−0.45; 0.18]	
	Connectivity			0.54
Outdegree	0.78	0.071	[−0.03; 0.65]	
Binocular Density	−1.61	0.008	[−69.13;−13.20]	
TVR-Personal Distance	0.28	0.682	[−32.04; 46.99]	
TVR-Social Distance	0.48	0.496	[−164.13; 316.70]	

Note(s): TVR = Targeted Visibility Ratio
Source(s): Created by the authors

Table A4. Regression analysis – Office B

	β	*p*	95% CI	R^2
	Connectivity			0.67
Degree	−0.33	0.462	[−1.23; 0.59]	
Density	−0.55	0.156	[−641.98; 116.91]	
Visual integration	0.14	0.723	[−0.06; 0.09]	
	Connectivity			0.22
Outdegree	−0.49	0.200	[−0.33; 0.08]	
Binocular density	−0.54	0.050	[−63.66; 0.08]	
TVR-personal distance	0.52	0.105	[−13.98; 125.32]	
TVR-social distance	0.10	0.812	[−364.50; 454.11]	

Note(s): TVR = Targeted Visibility Ratio
Source(s): Created by the authors

Table A5. Summary of the results

	Office A	Office B
Mean degree (SD) [CI]	17.53 (5.32) [14.59, 20.48]	23.07 (1.28) [22.36, 23.78]
Mean density (SD) [CI]	0.18 (0.04) [0.16, 0.21]	0.07 (0.003) [0.07, 0.07]
Mean visual integration (SD) [CI]	14.04 (6.05) [10.68, 17.39]	59.50 (14.36) [51.55, 67.45]
Mean outdegree (SD) [CI]	8.67 (4.48) [6.18, 11.15]	9.53 (4.69) [6.94, 12.13]
Mean binocular density (SD) [CI]	0.19 (0.07) [0.15, 0.23]	0.07 (0.02) [0.06, 0.09]
Mean TVR 60 (SD) [CI]	0.24 (0.07) [0.20, 0.27]	0.25 (0.01) [0.24, 0.25]
Mean TVR 150 (SD) [CI]	0.04 (0.01) [0.03, 0.04]	0.04 (0.003) [0.03, 0.04]
Mean connectivity (SD) [CI]	7.55 (1.76) [6.58, 8.53]	2.85 (1.23) [2.18, 3.53]

Note(s): SD: standard deviation; CI: confidence interval
Source(s): Created by the authors

Table A6. Demographic characteristics of open-plan offices

	Office A (n = 15) Frequency	Percentage (%)	Office B (n = 15) Frequency	Percentage (%)
Gender				
Male	4	26.7	10	66.7
Female	11	73.3	5	33.3
Age				
21–30	11	73.3	6	40.0
31–40	3	20.0	5	33.3
41–50	1	6.7	4	26.7
Occupation				
Architects	12	80.0	5	33.3
Interior architects	1	6.7	4	26.7
Drafting technician	2	13.3	6	40.0

Source(s): Created by the authors

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