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On the other side from you: How library design facilitates and hinders group work

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ABSTRACT

This paper describes a longitudinal ethnographic analysis of space usage in an academic library. We focus on group work, identifying a range of group types and activities. We address how the library space and users' technology choices impact the flow of information within groups, and finally identify some implications for both space and technology design.

Author Keywords

Libraries, space, awareness, group work, ethnography

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

The concept of the academic library as a silent, hallowed space dedicated to individual study is significantly outdated (Applegate 2009; Genoni 2013): academic library buildings these days house a variety of users working on a range of tasks (Fried Foster et al. 2007; Bryant et al. 2009; Bailin 2011). Many of these tasks are group tasks, and this style of work is increasingly popular in education at all levels (Cain 2013).

In tandem with the rise of group work has been a period of Library redesign, to better facilitate this type of work, and to make libraries more welcoming, friendly places (Sweeney 2005; Fried Foster et al. 2007; Bailin 2011). Despite such intentions, however, these changes are often either without any user consultation at all (see for example (Sussman et al. 2011)), or driven more by institutional imperative than user need (King 2012). Nor has redesign work typically addressed the information or technological context of users, whether that context is the use of the books provided by the library, or the number of user devices that need power.

While there is a strong history of ethnographic work in libraries (Khoo et al. 2012), the majority of this work has been aimed at addressing either the broad questions of what tasks users would like to perform in academic libraries (Bryant et al. 2009; Bailin 2011), or at very specific tasks where users interact with an individual system or process within the library (Lau et al. 2006; Hinze et al. 2012; Saarinen et al. 2013). Some work has

sought to identify what types of space are needed to support user tasks (Fried Foster et al. 2007; Cocciolo 2010), however little work indeed has addressed how users' work patterns are affected by existing library space, nor what those impacts mean in terms of information interactions within group work. In this paper we use ethnographic methods to examine the impact of space on group interactions within an academic library, in particular the use and sharing of information. An Australian academic library is used as a case study.

This paper is divided as follows: we first place our work in the literature, before describing our multi-phase study method and the library space it occurred in. We then report results, which we analyse and discuss, finally drawing conclusions and noting avenues for future work.

BACKGROUND

There are two key underpinnings to this research: previous work on library spaces, and the conceptual frameworks for interpreting and analysing the impact that library space has on group work.

Library spaces

The issue of academic library space has come to the fore in the past ten years with the changing nature of libraries. The increasing use of group assignments (Cain 2013) and online resources (as opposed to print books (Christianson et al. 2005; Connaway et al. 2011)) has changed the way students want and expect to use these spaces: they are no longer just spaces for individual work at study carrels; in fact one study has identified them as the 'center of students' days' (Fried Foster et al. 2007), where they eat, socialize, kill time, study, and do group work. Increased library building use is associated with increased student retention (Mezick 2007) (though not achievement (Goodall et al. 2011)), so even the non-academic uses of libraries are likely to benefit academic institutions. Contrary to the falling library use seen in the mid '90s (Martell 2008), it is once again common to see complaints that there is not enough space in academic libraries (Bryant et al. 2009; Cocciolo 2010; Bailin 2011).

The focus of library design in the past ten years has been on ensuring that libraries are places students want to use, and as early as 2007 some key characteristics of these spaces were identified (Fried Foster et al. 2007): they need to offer a range of possibilities for work, they need to be comfortable, they need to be technology-enabled or provide technology, they need to offer information resources, and they need to offer staff support. Perhaps the biggest change in the past seven years is that students now bring their laptops to campus (Bailin 2011), where they did not in the past (Fried Foster et al. 2007).

The need for a mixture of silent and social spaces is a recurring theme seen in the literature (Fried Foster et al. 2007; Gibbons 2007; Bryant et al. 2009; Bailin 2011; Goodall et al. 2011). Silent spaces are focused on individual work with information resources, technology or both; the primary complaint about these is that there are not enough power points to serve all of a user's devices (Bryant et al. 2009; Bailin 2011). Social spaces are more complex, however. These spaces might be used for individual work or formal or informal group work (Gibbons 2007; Bryant et al. 2009; Bailin 2011). While it is clear how we might design effective spaces for individual work—indeed libraries have traditionally served this type of work (Thomas, 2000)—it is less clear how to support group work. Early research suggests that shared displays and tables large enough to accommodate groups are necessary (Fried Foster et al. 2007); beyond this few of the needs of groups in libraries are known.

Many library spaces are organized on regular, geometric, and often square patterns. Recently though, there has been a move to more 'creative', informal spaces, drawing on new movements in interior design that draw on similar themes in work places such as Google (Kurt et al. 2010).

Our study addresses a gap in understanding about library use: how space, people, information and technology interact, and the implications for library and technology design, particularly when it comes to group work.

Conceptual framework

There are a number of frameworks useful in discussing co-located academic teamwork, including space syntax, co-reading, the CSCW literature, DiCOT and proxemics.

In one form, the impact of space on groups has been observed in the study of both city-scale and building-scale planning (Sailer et al. 2010). Research in these areas has led to the development of 'space syntax', linking physical structure to the support of activities undertaken in the space. Informally similar lessons can be drawn for the arrangement of space in libraries (as shown above).

On a smaller scale, recent research has examined the operation of small reading groups, and their technology needs. Marshall et al (Marshall et al. 1999) first examined the use of technology in reading groups, while Pearson et al (Pearson et al. 2012) examined more closely the internal interaction within a group, and provided an initial categorisation of group co-ordination tasks. Similarly, Morris examined collaborative search behaviour (Morris 2013), contrasting it with the needs of individual search. The key point of Morris' findings is that familiar tools predominate in practice, though they are demonstrably imperfect, and that social media and 'real world' social networks are used extensively for finding material.

The CSCW community has also examined the impact of physical space on group work. Simple models such as the CSCW matrix (Johansen 1988) remain helpful for analysis, while Dourish's separation of 'space'—the precise physical location—and 'place'—the meaning or role of the location, virtual or real—has proved pivotal in many contexts (Harrison et al. 1996). However, Dourish has complained that later researchers have adopted the

concepts without understanding the underlying theory (Dourish 2006).

A further approach that has been used to analyse work in complex environments has been distributed cognition (DC) (Hutchins 1995). Recently, Blandford and Furniss (Blandford et al. 2006) have introduced DiCOT (Distributed Cognition Of Tasks), which provides more analytical power when examining teamwork in physical space. DiCOT has proved valuable in formal teamwork settings; in this paper we use it to examine the workings of informal groups.

Finally, proxemics (Hall 1966) has been used to evaluate group interactions: how people connect with each other is certainly relevant to group work. We consider it here but its analytical power is limited as it focuses on interactions between people but not with technology.

While each of these frameworks captures some elements of co-located academic group work, none encompasses the full range of interaction between people, task, technology, information and space: the specific aim of this study.

METHODOLOGY

As outlined above, ethnographic methods have a long history in the study of libraries (Khoo et al. 2012), and have also been used to inform technology (Marshall 2010) and space (Fried Foster et al. 2007) design. Our case study continues in that tradition. It is a multi-phase investigation into how groups and, in contrast, individuals use the physical space in an academic library to work.

As with all ethnographic work, physical context is important; we will first describe both the institution and the library where this work was situated. Second, we describe our multi-phase approach to understanding group work within that context.

Study context

This work used the library on the main campus of Swinburne University of Technology as a case study (each Swinburne campus has a single library). The Library is a central gathering point on the campus; until very recently it housed the only public student-access computers on campus, and represented the majority of public access indoor study space. As a result of this, the space has often been over-subscribed, and the study presented here was driven in part by a need to layout and use space more effectively. The library is spread over a number of floors, and includes a variety of types of space.

Silent study space: The two uppermost floors of the library are silent study space, offering a mix of public access computers and powered and unpowered desk spaces. Types of seating include traditional carrels, long benches and round or oval tables with low dividers. This area holds the majority of the Library's book collection.

Informal group study spaces: Large areas of movable tables and chairs in spaces where noise is permitted. One of these spaces also incorporates fixed bench tables with power for laptop use—we refer to these as 'finger tables'. Their low central divider and rounded ends mean they are often used for group work.

Computer benches: A number of zones within the library offer long benches with fixed desktop computers.



Figure 1: Computer pods

Computer pods: These provide a second type of PC desk, having desktop computers with larger screens on curved tables. Sets of pods create geometric shapes (Figure 1). Pods are confined to two zones where noise is accepted.

Lounge spaces: Small areas of comfortable lounge-style seating scattered throughout the Library's social zones.

Group study rooms: There are a number of group study rooms in the Library. These can be reserved in advance but are available for use without a booking if unoccupied. They each provide a room with a door, a shared large display, a table and chairs. All rooms have glass walls, and the display in most of them can be seen from outside.

Booths: As an alternative to group study rooms, booths are provided in two zones of the Library. Three booths have large shared displays, all have padded bench seating and fixed tables, and seat 6 people comfortably.



Figure 2: The Hub, designed group study space

The Hub: This is a purpose-built group study space adjoined to and accessible only via the Library (see Figure 2). This space has high round tables and chairs and low round tables and lounge seating. Both types of seating are moveable, but they are arranged into small zones within the overall space. Most of the walls can be written on with dry-erase markers. The overall zone also houses a number of group study rooms and booths.

As we can see, this library comprises several different physical arrangements, and thus provides an opportunity to contrast the behaviours in different areas. This is a sharp contrast to other recent library studies (Bryant et al. 2009) which have tended to provide primarily "square" arrangements of desks, or which are in periods of transition where more modern and less symmetrical arrangements are only beginning to be adopted.

Multi-phase Approach

This study was a three-phase investigation into how groups and, as a contrast, individuals used the physical

space of the library to work. The three phases were a longitudinal examination of space use, a more focused and exploratory investigation of group work as a phenomenon, leading to the creation of a number of group archetypes, and close observation of sample groups from each of those archetypes.

Longitudinal Examination of Use

The longitudinal part of this study encompassed an entire semester, including study breaks, up until halfway through exams. Once per week on Wednesday afternoon (a time identified as busy by Library gate counts) a headcount of all library users was taken floor by floor. The purpose of this headcount was to track total usage, and to identify how the space was being used. This headcount thus included not only raw numbers per floor, but also a number of other features including laptop use, book use, tablet computer use, group work (and size) and number of library users in the stacks. It was during the initial weeks of this headcount that the salience of group work emerged.

Consolidation of group data

This phase involved examining groups more closely from a variety of perspectives. Early work in this phase comprised noting for all groups seen during the weekly headcount how many people there were, whether they were using books, notebooks, tablet computers, laptops or desktop computers, and what type of seating they were using. Following this a closer examination investigated the types of activities groups were doing, and involved repeated counts over a fortnight. From this close examination, a group typology was developed (see the results section for more details) and a series of counts was done to identify the relative frequencies of these groups. Upon consolidation of this typology, close observation was used to determine how the space affected group interaction and information sharing.

Close observation

This phase consisted of targeted observation of groups within each category of the typology developed in the previous stage, with a single exception (discussed below). These group types were observed the relative proportions in which they appeared in the Library. These close observations first required identification of what groups were doing (to categorise them), and then included noting how groups were configured in the space, what technologies were being used by whom and for what, and noting interactions taken to co-ordinate information.

RESULTS

In this section we first present overarching results from our longitudinal observations, before describing the group types we derived, and finally study the findings of the close observation phase. The evolutionary approach taken means the analysis from one phase forms data in the next.

Longitudinal study

In the first part of the study, we simply took headcounts of the patrons in each zone in the library building. Note the sharp dip in use between Easter and ANZAC day¹;

¹ A public holiday in Australia and New Zealand for commemorating fallen members of the armed services

while teaching was technically in session, it was a 3 day week and utilisation was low (See Figure 3 below). The quiet space in the library is on the top levels, and as such less likely to be chosen by users without a particular preference. Nonetheless there is a spike in solo use of the social space around week 6, when quiet space was full.

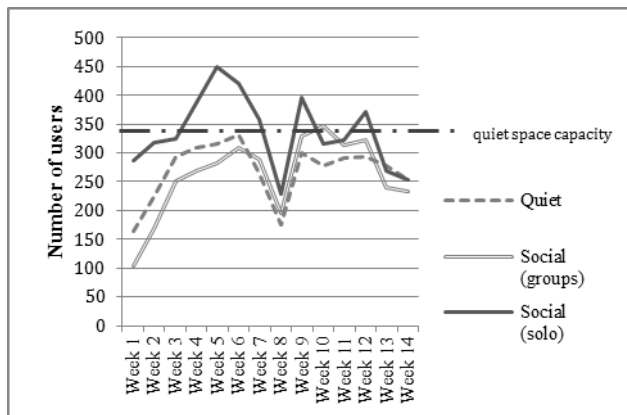


Figure 3: Raw usage of space by usage type

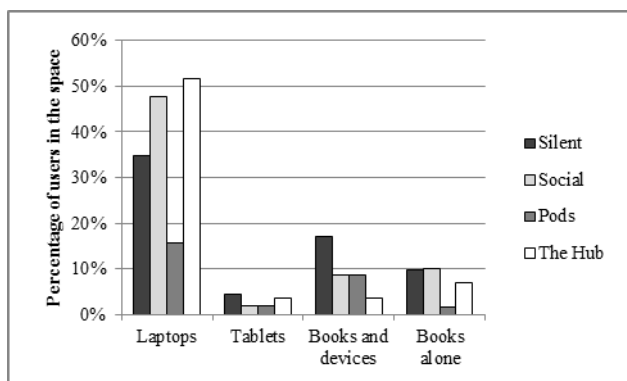


Figure 4: Technology and book use by space type

The pattern of personal technology and information use varies by area, as seen in Figure 4. Unsurprisingly book use, and particularly book use without concurrent technology use, was low in pod-type space, which is dominated by desktop computers. It is perhaps surprising, though, that book use with devices was notably low in The Hub. While there is no reason related to the facilities or furniture why this should be so, this space is more removed from the main library than any other space, perhaps affecting book use. Overall tablet use was low, though slightly more common in the silent areas.

The relative frequency of group sizes stayed broadly the same throughout the period of this study, but there was a peak in the number of trios and quads just before a peak in pairs (see Figure 5). This is likely due to deadlines for group assignments. Naturally enough, pairs predominate.

It is interesting to note where groups worked (see Figure 6): pairs were the majority in nearly every space, but this preponderance was much more pronounced in a space that was entirely comprised of curved pod desks. This demonstrates clearly that the configuration of space at the macro level has an influence on group behaviour: we only saw larger groups in this area when the library was very full; probably as it is ill-suited to larger groups.

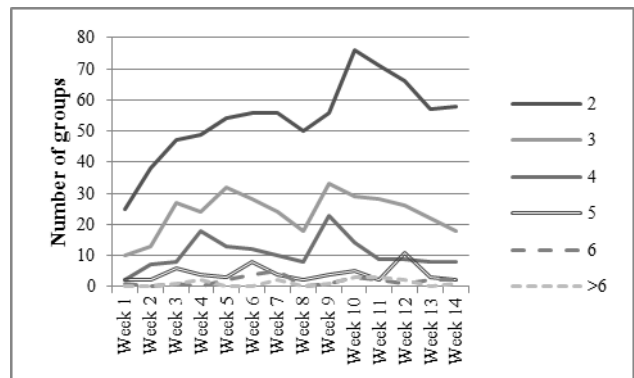


Figure 5: Group sizes over time

Conversely, pairs were rarely seen in group study rooms; these spaces typically had three or more people in them. Group rooms can be reserved, and larger groups took most advantage of this option. It also probable that larger, perhaps more organised, groups preferred the reduced noise of a closed space: the open group study areas can be very noisy during busy periods, and closed rooms will reduce the problems of communication in larger groups.

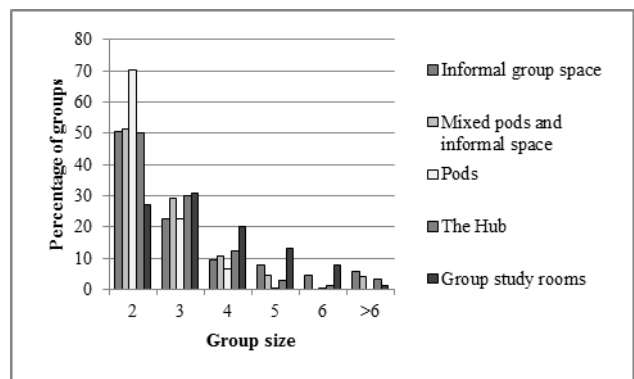


Figure 6: Group sizes by study space type

Group Types

Following the first phases of observation, we formulated the following group types:

Co-Production Groups: engaged in producing an artefact such as an essay, presentation or CAD diagram. In larger groups, this could involve visible sub-teams or individuals with specific, visible roles (e.g. fact checking, editing or coordination).

Co-Reading Groups: collaborative reading of one or more documents. This is typically evidenced by copies of a common text, in digital or paper form, and utterances that revealed co-ordinated reading of a single document.

Co-Production/Reading Groups: in this hybrid group type, both production and reading activity was visible, but reading was, unlike in a co-reading group, not necessarily undertaken by the whole group.

Loose Study Group: a group studying and working on a common exercise, problem or topic, but without the need to produce an artefact (in contrast to co-production), or reading alone (cf. co-reading). These groups were identified through common worksheets, textbook or other exercises, and discussion of the right answer, or the meaning of a particular term. These groups would have

occasional lapses into social and leisure discussion, but were mostly focused on the task at hand.

Social/Work: these groups were typically smaller (rarely more than four people), and were engaged in individual tasks while socialising intermittently with their neighbour. The use of different materials and limited mutual engagement was indicative of this type.

Purely Social: no evidence of study or work, but with a high level of social discussion and contact.

Rehearse Talk: Frequently found using the group rooms, these groups had one or, rarely, two members, who were speaking to slides (of which parts were often unfinished or had other signs of imperfection). Other members may be taking notes or asking questions. This group type appeared almost exclusively in group study rooms, and as such is not expanded on in more detail.

We also encountered some other groups, such as sit-down meetings, but not in sufficient numbers to justify identifying an explicit classification. Collating our results from three complete counts using this scheme, we got the following cumulative counts (with largest group size):

- Co-Production: 44 (5)
- Co-Reading: 28 (5)
- Co-Production & Reading: 22 (4)
- Loose Study: 27 (7)
- Social/Work: 26 (5)
- Social: 13 (7)
- Rehearse talk: 6
- Uncoded (unable to identify group): 74

The relatively high number of uncoded instances was primarily caused by practical difficulties in observing every group, and the risk of excessive intrusion. Median and mean group sizes were similar between the different types, but the distribution of larger group sizes was skewed towards loose study and social types.

Close Observations

The final study phase comprised twenty close observations of specific groups to examine the group types in detail. As we knew the relative proportions of group-types, we targeted our observations to get a representative (sample see Table 1). In this section, we identify each group by its number (e.g. G5), and members by gender and number (e.g. F2, M3).

Some zones proved more difficult to observe: we only conducted a single observation (G19) in the finger-table area, and it was impossible to observe group meeting room activity. However, as seen in Table 1, most of the group activity occurred around the desks and PC desks.

Co-Production Groups

This was the most common group type observed in the previous phases. We observed eight groups, and the shape of desk space they used varied: 3 used rectangular tables, 1 a straight-edged PC desk (G20), 2 round tables, and 2 curved PC desks.

In the groups that used round tables (G1, G11), each member had an individual view of a screen or other

information, which was partly or entirely obscured from the rest of the team.

A similar layout was found in G2, where two members, on a long side of the table shared their view space, but the other two were obscured from each other as observed at the round tables. G6 had an almost identical layout. The two-person G4 used the side-by-side arrangement seen within the four-person G2 and G6 teams. While they had individual technology and separate laptops, (as was also the case with the pairs in G2 and G6), accessing each others' work was easy.

In all these groups, there were regular exchanges about each other's work. e.g. in G1 M3 asked his teammates "A" no longer exists, right?" and minutes later M2 said 'here's the update', warning M3 of an email from him.

The three groups using PC tables, curved or straight, had a different structure and strategy: while the previous groups had fragmented views, G8, G18 and G20 all had a single large screen in use as the centre of attention, with one member 'driving' the technology while the others looked on (G8, G20), performed ancillary referencing (G18), or took or referred to notes (G8, G18).

Table 1: Groups in the close observation phase of the study

Group No.	Group Size	Desk	Activity
1	5	Round table	Co-Production
2	4	Rectangular table	Co-Production
3	3	Rectangular table	Loose Study
4	2	Rectangular table	Co-Production
5	2	Rectangular table	Social
6	4	Rectangular table	Co-Production
7	5	Rectangular table	Loose Study
8	3	Curved PC desk	Co-Production
9	3	Curved PC desk	Loose Study
10	3	Curved PC desk	Social/Work
11	2	Round table	Co-Production
12	3	Rectangular table	Co-Reading
13	2	Curved PC desk	Co-Reading
14	6	Round table	Loose Study
15	3	PC desk	Co-Reading
16	3	Round table	Social/Work
17	6	Rectangular table	Social
18	3	Curved PC desk	Co-Production
19	3	Finger table	Co-Reading
20	4	PC desk	Co-Production

The problems of obscurity in the desk-based groups were readily identified due to the simple fact that a screen facing away from a group member could not be visible to them. Group members often turned laptops or paperwork to show material to their colleagues, and members moved around to see each other's screens: e.g. in G6, who used individual laptops, F3 moved around beside F2 in order to see her screen, following an exchange between F1 and F2. A further conversation followed, which ended in F3 returning to her seat, while F2 made changes, confirming them verbally with F1, making comments such as 'Let's move that over the page', while F4 was drawn into a conversation that led her to say 'I'll explain that...here'.

Members of G1 also moved, and like G6 provided a number of examples of rotating laptops. All groups had one or more occasions where a laptop was turned to show content to others, either for just moments (G1) or an extended period (G2).

G20 demonstrated the problems of a long, straight desk and a single device. Members had to stand behind those seated at the PC or their view became obscured. After a period, any standing member moved aside and sat down with a less clear view of the screen.

In groups where multiple screens were present or members had individual views (such as G6), spoken updates were necessary to avoid errors and maintain awareness. In contrast in groups (or subgroups) where there was a shared screen (such as G8, and G6's subgroup of F1 & F2) editorial decisions were discussed ahead of time but the shared view meant that there was no need to confirm changes had been made, or issue cautions that they were about to be made.

The density of technology naturally varied between the two arrangements. Across the four larger desk-based groups (G1,2,6,11), there were 12 laptops, 1 tablet, a notepad and a mobile phone in active use—every member engaged with some personal technology, digital or paper. In contrast, in the three PC table groups and G4 (the pair), there were two laptops, one image, a notepad and 3 PCs. In G4 the laptop and image were both shared resources. The three PC groups each used a single large-screen PC as a shared main device. In G18 the notepad and laptop supported intermittent secondary tasks. The group members were, with one exception in G18, looking at a common document. In each case at any moment the group's working document was controlled by one person.

Co-Reading Groups

There were four observed groups of this type: G12, G13, G15 and G19. The number of reading groups fell gradually across the longitudinal observations, likely as assignments moved from preparation to conclusion.

Two groups revealed a link between collaborative reading and coursework: G12 were heard to say 'what does it say in the brief?' and they discussed the relevance of 'volume projections' and 'empirical metrics' to an assignment. A member of G19 cautioned that the lecturer had said 'that was a bad point' as they discussed an essay structure.

The other two groups appeared to have met to learn new skills or ideas: G15 were examining argument and statistics in an academic paper. G13 were studying a set of lecture slides (from another institution) and taking notes from those slides onto printed lecture handouts.

In contrast to co-production, there was little evidence of clear spatial patterns. The number of individual media items was higher, and the task structure was, beyond the two motivations just given, more variable.

Co-reading groups used a variety of desk types, and as with the co-production groups, this coincided with the structure of their interaction. G15 serves as an example: originally two members, F1 and F2, were working side-by-side, each with their own PC and view of a common document; they were then joined by a third member, F3, who F2 had said they should find. F3 set up her laptop at right angles to the existing pair, next to F2. She could (and did) rotate it to show material to F2, and, on two occasions, F2 then demonstrated the same to F1, using

her screen, which F1 could readily see. In G12 two members similarly rotated their laptop screen; one also held up a handout in order for the other two to see, while in G19 F1 had to stand up in order to view F3's screen.

G13, a pair, read together from a large PC screen. F1 referred to a textbook in her lap, occasionally read aloud, and also referred to some loose handwritten notes; in the meantime F2 took notes in a notepad and annotated a printout of different a set of lecture slides, than those shown on the screen. In G19, different laptops and media were used either by a pair or by all three members; F1 referred to a textbook as required, and F2 and F3 took notes at different times.

Throughout, as in the examples just given here, there was frequent note-taking by members of the groups, and three groups included the reading out of additional material by one or more members. These behaviours were far less commonplace in the co-production groups; a unsurprising discovery given that annotation is more heavily associated with reading than writing (Marshall 2010).

Co-Reading and Co-Production

As already noted, many groups in the library were seen to be combining co-reading and co-production. In the twelve groups specifically labelled co-reading or co-production, four demonstrated combined behaviour: G2 and G4 in the co-production set, G12 and G19 in the co-reading set.

Within co-production, co-reading occurred in small subgroups. In G2, a two-member sub-group, F1 and M2, sitting side-by-side, undertook reading to support the group's task, mirroring the arrangement of G4's pair of members. In contrast, the co-reading groups that were preparing for an assignment, while focussed on reading, undertook short bursts of individual work.

Our observations suggest two things. Firstly, co-reading often happens in anticipation of, and to support, co-production, and that co-production, at least in some cases, relies on collaborative reading to underpin its progress, as seen in G12 and G19 (co-reading). Secondly, the volume of reading, is high at work's outset (to set scope and acquire new skills), and declines as the work moves towards production and writing-up. In turn this means that the relative proportions of groups seen in this case study are unlikely to be fixed over the course of a term.

It is significant that co-production and co-reading usually used different spatial structures. When sub-groups in co-production teams entered co-reading, they were already in the same physical position—side-by-side—that was adopted by co-reading groups who shared the an artefact. Thus, the division of needs is not as clean as the two types of group, taken in isolation, would suggest. A key following question is whether or not co-production groups consciously chose their layout (out of habit, intention or otherwise). Conversations about seating as groups arrived were at most brief, suggesting that the co-reading sub-groups are more likely to be incidental results of seating, rather than intentional strategy.

Loose Study Groups

Four study groups were observed (G3, 7, 9, 14). They used a variety of table formats, and demonstrated a third configuration of space. While individual materials were key, this co-existed with frequent, changing sub-groups, and within those the use of shared views was common. However, these shared views lasted longer and more alongside individual work than seen in co-reading or production.

In G3, F1 took the lead, working together with M2 and M3, on an accounting worksheet (with textbooks on accounting and mentions of profits and transactions); M3's tablet was twice used as a shared view; he turned it to show the screen to M2 and F1. At the same time, M1 and F1 each had separate copies of a worksheet printout, and F1 shared at length with M2 at using her tablet. F1 and M2 took notes as they worked, while M3, who was mostly unengaged and interacting with his mobile, would verbally explain technical issues of the calculation to the other two. In DiCOT theory (Blandford et al. 2006) verbal representation is a shared medium akin to visual material; thus within a span of (much) less than ten minutes, we were able to observe seven different shared presentations. This density of change was unparalleled in the reading and co-production groups.

The six-member G14 also worked individually on printed exercises. In this case, F4 got up from her chair and then stood between F2 and M3 as they discussed a particular equation (references were made to $10x$, x^2 and cosine x). Concurrently, M6 was reading material on his tablet and discussing the same problem with M5 (and having side exchanges with F2) while they (M5 & M6) shared a single copy of a handout. Moments later, the group reconfigured itself with F4 returning to her chair, while M3 took some further notes ('I'll take a note of that').

These groups also moved between work and social roles. Just as our observation of G14 began, the group laughed loudly and M6 said 'That one never gets old'. Similarly, as M3 took his notes, the group turned to social gossip.

Social/Work

Groups G10 and 16 were the two social/work groups. In G10, M1 was switching between an online timetable and Swinburne's online learning environment, while M2 was examining and editing a long Word document while intermittently turning to his phone. Both were initially browsing Facebook, and were later joined by M3, who quickly opened his laptop while being introduced to M1.

G16 also featured a lot of phone interaction. M2 shuffled between Facebook, Word, and his phone. He referred to the performance of a local sport team, which had 'got smashed, eh?' in a recent game. M1 was preoccupied by his phone, but engaged in the social dialogue while M3 searched a database and read an online forum.

These groups were not heard to discuss work. Social talk predominated, with varying visual contact. Members twice viewed others' screens to see leisure content, but visual attention was primarily on their own devices. One common pattern in both the longitudinal study and observation, was students sitting on alternate sides of the

table. While keeping students near to their colleagues, this minimised the visibility of screens to the rest of the group, controlling, perhaps, either distraction or privacy while allowing for eye contact to support socialising.

Social

G5 and G17 were the two observed social groups. G17 was an established group seen a number of times. G5 was a group where work dissolved into socialising when a second member showed up. They discussed lending USB sticks, and sharing videos ('I swear he put it on this USB'—'Do I even want to watch this video?'). Socialising in the Library, therefore, happened on both a planned and ad hoc basis, and involved lots of chat, shared visual focus and sometimes shared media.

ANALYSIS

Having addressed the different types of group, we now synthesise some of the insights generated by our study.

Space and Task Structure

A variety of structures emerged across and within the different group types.

Personal Working Space (PWS)

One common structure occurred where individual group members maintained a personal working space (PWS) that had limited or no access for others. This configuration happened at both round and rectangular tables, with group members facing inwards. In this way visual contact was maintained, leaving verbal communication the means of co-ordinating work.

The PWS configuration appeared to be associated with separate tasks: social/work groups often appeared to adopt this approach (seen in six social/work groups in the intermediate phase of our study) specifically because it retained the opportunity for eye contact while obscuring screens or other work.

Perversely, PWS was also frequently seen in groups where at least some co-ordination was necessary, such as loose study groups and co-production groups. In all our observations of these groups, tasks were less tightly coordinated where users had individual views of content and technology than when they adopted a shared view. In moments of closer collaboration, group members either had to re-orient the space, or talk extensively. Adjustment included group members moving (5 occasions: e.g. F4 in G15, loose study, F3 in G6, co-production) or turning material to present it to other members (9 occasions: e.g. M3 in G3, Loose Study). Workarounds included longer verbal exchanges and reading aloud (41 events: e.g. F1 in G12, co-reading). Some groups seen in the earlier phases appeared to use large screens in the group study rooms as group scratchpads, providing a consistent location for exchanging material or ideas.

Shared View (SV)

The second common structure emerged when two or more group members (and occasionally all of them), engaged in a single shared view (SV). For whole groups, this occurred in cases of co-production and co-reading, with a single view of a document (e.g. G18, co-production). This could be supplemented with individual content via a laptop (e.g. M2, G18) or notepad (e.g. F2,

G13, co-reading). In this structure, the group members almost always faced in one direction, and in small groups and pairs within groups, typically sat side-by-side. However, with larger groups, especially with long straight PC desks (e.g. of 4, G20), the physical space required members to stand behind others to see the same view, and members stood aside from time to time to sit down, temporarily disengaging from the view (as indeed happened with G20). In contrast, concave desks (see Fig. 7), as used by G18, appeared to serve groups of three or four better, gathering the team together, and moving workspace for secondary tasks to the side of the group.

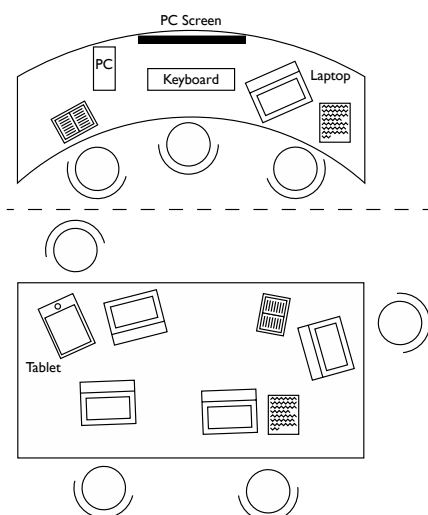


Figure 7: Group arrangements: Concave single view (top) and convex personal working space (bottom)

Individual Copy (IC)

A third group structure emerged in co-reading and study groups, where each member had an individual copy of a common document (IC). Occasionally a member lacked a personal copy and shared with another; nonetheless this structure allowed a flexible combination of personal and group activity (e.g. G14, Loose Study). However, many of the problems of co-ordination found in in PWS activity re-appeared.

Task vs Space

A summary of the different space usage types can be seen in Table 2.

Our data demonstrates that reading is far from the only activity taking place in the library. Tables 1 and 2 show that different activities and require different kinds of space. The visual control of content was central to the organisation of the different spaces and tasks. While individuals or small sub-groups worked independently for short spans of time, co-ordination with the rest of the group required the sharing of information or plans. This in turn led to group members moving around, rotating books and screens, verbal communication and occasionally the passing of notes and even emails.

While the role of space has been researched in the context of collaborative reading (Pearson et al. 2012), the role of physical factors in collaborative information behaviour is embryonic (Ingwersen et al. 2006; Amershi et al. 2008).

Different group tasks appear to influence contrasting choices of spatial organisation.

Rectangular desks work well for groups working around a set of personal workspaces, or for pairs, but shared views for groups of three or more work better in concave spaces. Concave spaces are relatively rare in libraries, but uniquely suited to highly co-ordinated work, and their popularity is clearly evident in this study.

Personal requirements also varied: in co-production most group members interacted with one device or medium, while in co-reading and, to a lesser degree, study groups, most members continually swapped between different items, such as a handout, textbook and notebook or laptop. The need to view one item, while taking notes in another (as also seen in (Marshall 2010) expanded the space needed by each member, only a pair consistently used a shared view for reading.

Table 2: Group types and behaviours

	PWS	SV	IC
Amount of space	Larger	Smaller	Medium
Eye contact	Frequent	Limited	Variable
Verbal coordination	Co-ordinating sub-tasks	Negotiating action	Co-ordinating display
View of task document(s)	Individual items	Shared item	Individual copies
Shared Awareness	Speech, rotating tech and documents	Centred on shared screen	Pointing and rotating documents
Co-ordination	Loose, often many sub-tasks	Focus on screen, some subtasks	Close and frequently negotiated
Copies of task items	One or more	One	~1 per person
Shared Technology	None	Large display, control shared sequentially	None
Personal Technology	Laptops, phones, tablets.	Optional secondary laptop or tablet	Laptop or tablet if reading online
Print matter/notebooks	Both individual and shared	Rare, individual	~1 per person
Control	Devices private, controlled by owners	One member in control of shared display	Personal views controlled by owners
Table type	Convex	Concave	Convex

The near-complete absence of discussion about where to sit in our observations suggests that these choices are probably at least partly subconscious; the crowding seen in the target library also reduces choice. Groups occasionally switch between tasks (e.g. from loose study to social, or from social/work to co-production), and with that needed to reconfigure their use of space.

Against these patterns of behaviour and space, how well do established library spaces support group work? The answer is, generally, poorly; highlighted by the success of many non-traditional layouts observed in this study. Long, thin desks (e.g. G20) provide poor support for both individual and shared sub-tasks, and limit vital mutual awareness: both visual and verbal communication become much more difficult.

Public and Private Devices

While students often rotated laptops to show others the screen, it was almost unknown to see control of a device

handed over to another group member. Even where control was handed over, if the laptop did not belong to Swinburne, the putative owner oversaw the new user. This was in sharp contrast to (public) desktop PCs, which were frequently used by co-production groups even when laptops were present: control frequently moved between members. There is a clear distinction between public and private devices, with USB keys used to mediate between the two (as observed with the sharing of files by G5). The absolute prevalence of this distinction was made clear by the single occasion when a pair was observed to swap private laptops: the act was a notable and jarring contrast.

Roles and Co-Ordination

Several roles repeatedly emerged within groups: e.g. the scribe who input text on behalf of the team (especially in single-screen co-production); the editor who co-ordinated changes to content (multi-screen co-production), the co-ordinator who facilitated different activities or conflicting needs between the group, and the teacher who often sat back until they believed their advice was required. These roles strongly interacted with the spatial structure of the group: e.g. shared-screen editing involved the scribe role, but eliminated the editor. All roles became more distinct in groups of 3 or more. In single-view groups, the co-ordinating person sat, or stood, towards the back of the group: maximising their awareness of the team.

Groupware Use

In a number of contexts, readily available technology could support some of the group activity. G1, for example, used email to pass updates, but were aware of Google Docs—M3 explained Google Docs to M2 when he complained ‘there has got to be an easier way!’; similarly G6 passed USB sticks, while also commenting on Google Docs. Though students were aware of collaborative tools, we did not observe the use of any groupware. This suggests a preference for familiar tools even when they are discerned as sub-optimal, mirroring similar traits in information behaviour generally (Warwick et al. 2009). It is possible, though, that dividing work improves role-taking and contextual awareness.

Roles and Technology Use

Team members occasionally took on roles such as ‘group web searcher’ (G1, G19) or ‘note reader’ (G13) especially in co-reading and shared-view co-production tasks, relieving a load from the closely co-ordinated central group. Where a shared view was central, these roles were often taken by a member at the edge of the group who was turned away from the main group’s view. As noted earlier, concave table shapes served these needs better.

Students repeatedly needed to demonstrate a process, or show an artefact. This could prove clumsy, with laptops and books being rotated, fingers pointed, and material read aloud. There are many potential strategies for alleviating these problems, but the reticence towards new software suggests that technologies such as screen mirroring, VPNs, etc. may have low uptake.

This reticence is also seen in content sharing. Students co-opted social media tools—G18 used Facebook to work with another group—and G1 knew of Google Docs, but

had decided not to try it. While more advanced tools may prove helpful, caution again needs to be applied when acquiring new skills is resisted.

DISCUSSION

Our findings cast new light on established tools, such as DiCOT, proxemics and space syntax.

DiCOT focuses on analysing group work, and space is seen as a key issue. DiCOT can, for example, explain the presence of subtasks at the margins of concave spaces: an edge location avoids conflict between the main and sub-tasks, but retains, through verbal representations, a means of mutual awareness. Similarly, the primary shared view display, forms what DiCOT terms a ‘hub’; a place for making data available to a group. In contrast, in a circular arrangement of group members, DiCOT would note an increase in mutual awareness through eye gaze and speech, but that information flow is impeded when, for example, laptops form visual barriers. Unfortunately, DiCOT lacks a systematic understanding of spatial cause and effect, leaving a gap in the method.

Proxemics partly fill that gap: e.g. diagnosing distances that boost mutual awareness in work groups (Hall 1966). In the social/work and social group types, proxemics proved helpful to confirm the connectedness of the members: e.g. sitting on alternate sides of a table caused groups to sit within each other’s personal space.

The format of both the social and work-focussed groups is also partially explained by Harris and Sherblom’s work on small team communication (Harris et al. 2011). They focus on the influence of seating on person-to-person communication, and this is helpful for example in understanding the benefit of concave space for co-ordination in shared tasks, but their method is unable to explain the problems caused by G15’s material layout, in co-reading, nor the advantage of the central display.

Our observations revealed the orientation of work items, in relationship to group and individual space as a key influence on the effectiveness of collaborative work. The visual availability of colleagues, devices and paper are important factors. We therefore need to both extend and connect diverse approaches. It is here that space syntax is one potential starting point. While a contested approach in architecture, it has proved useful in understanding issues of orientation and visibility in interior spaces: highly relevant to the role of information in our groups.

CONCLUSIONS

Our research uncovered a small-scale ‘space syntax’ of group work in the library that demonstrates the pivotal role of space in the task-effectiveness of groups. The most common formats of desks and seating poorly match the spatial configurations that students create, and rearranging these configurations is difficult. In contrast, work moves fluidly between different (sub-) tasks that require different layouts. Two primary structures emerged: one focussed on a shared view, the other providing personal workspace.

Previous research on information work has emphasised the issue of awareness in collaborative work in reading,

and has connected reading to writing and rehearsal work. It appears that as co-ordination and awareness are central to students' collaborative work, theories of collaborative reading are likely to be more widely applicable. However, in HCI, our tools of analysis for small-scale space use are still embryonic, and further work will be needed to improve our ability to both interpret and design space use.

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