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Sociokinetic Analysis as a Tool for Optimization of Environmental Design

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SUMMARY

For centuries, architects and planners have pursued the design of human environments with the understanding that a relationship exists between social behavior and the particulars of the built environment. Examples of designs abound which were intended to encourage (or to discourage) specific modes of interaction, from Baron Haussmann's construction of the grand boulevards of Paris to the communally minded dormitories of the Fourierist and the Shaker utopias.

Despite the amount of theory which has been applied to the precise relationship between social and human behavior and the environment – which we may think of as the arena in which these interactions take place – only one study has been conducted which sought by quantitative means to identify the elements of a given environment that would render it ideal for its intended use. In his study *The Social Life of Small Public Spaces*, sociologist William Whyte innovated a method for critiquing the design of public parks that was unique in that it sought to objectify the critical criteria. The sole criterion in Whyte's study was whether people used the parks he studied, and whether they engaged in social interaction while doing so (1). As a result of his work, radical changes were made to the design of public plazas throughout New York and other metropolitan areas; despite this fact, this important effort has yet to be duplicated or expanded upon.

One of the experiments developed for the Lunar-Mars Life Support Test Project (LMLSTP) Phase III test was designed to develop this idea for application to the design of enclosed environments, such as those for long-duration space missions.

Introduction

What is social interaction? In terms of the built environment, social interaction is a dynamic constant that expresses itself as a kind of *kinesis*, or a choreographic pattern, by which the members of a group occupy a given place. The impetus and effectors to any given interaction certainly lie partly in the realm of personal and group psychology, and behavioral psychology shows us many ways of viewing the inherent relationships within any set of group transactions. However, personal or subjective studies alone are insufficient to explain the full set of behaviors that we describe as social interaction, in no small part because the environment in which these interactions happen contains formal elements which (whether by accident or by design) tend to stimulate or to suppress specific behaviors.

In general, these cues seem almost impossibly complex to identify, isolate, or characterize in terms of their behavioral impact. The design of hermetic habitats for long-duration human support in extreme environments (e.g., Arctic/Antarctic research, space exploration, or lunar/Mars bases), however, renders the need to do so as a matter of the highest importance. Under such circumstances, the habitat itself takes on a uniquely influential role as the primary or sole environment and is thus critical in either supporting or undermining the mental health, productivity, and interactions of its inhabitants. Therefore, the conscious control of environmental cues such as programming, acoustics, and orientation becomes fundamental to the facility's design and, by extension, to the success of the mission.

In order to enable the architect to exercise such control with any kind of precision, tools must be developed that are capable of generating hard requirements based on objective data. One such tool is **sociokinetic analysis** – that is, the study of the patterns in which a group of individuals within a given environment make use of that environment. This method involves a) the capture of hard data on the use of volumes within a hermetic habitat and b) the application of statistical analysis to their use by a resident group. Strict documentation of the habitat is then weighed against the results in order to force certain environmental design cues to the forefront.

The sociokinetic analytical method was pioneered at NASA's Johnson Space Center (JSC) in 1997. Its first run involved an objective study of the use patterns of JSC's 20-foot chamber during Phase III of the LMLSTP over the 91-day time span from September through December 1997.

Test Conditions

Camera locations included two cameras mounted on Level One, one mounted in Level Two, and one in the corridor area of Level Three. The following floor plans show the levels and the camera locations:

Level One — Camera 1: Common Room and Camera 2: Airlock

As the floor plans suggest, Level One was a multifunctional area consisting of galley and wardroom, science workstations for advanced life support studies, the principal personal hygiene and waste compartments (shower and toilet), and a dedicated exercise area in the airlock. The airlock was smaller than other rooms and was loud when any one crew person was using it for exercise. In addition, the airlock was the only location in the chamber from which the crew could be observed by anyone walking through the Building 7 highbay.

The common room housed the entertainment center (TV and VCR) as well as the only table large enough for communal activities or large work tasks. Despite its cramped and interstitial location, it housed all of the equipment most desired for group functions.

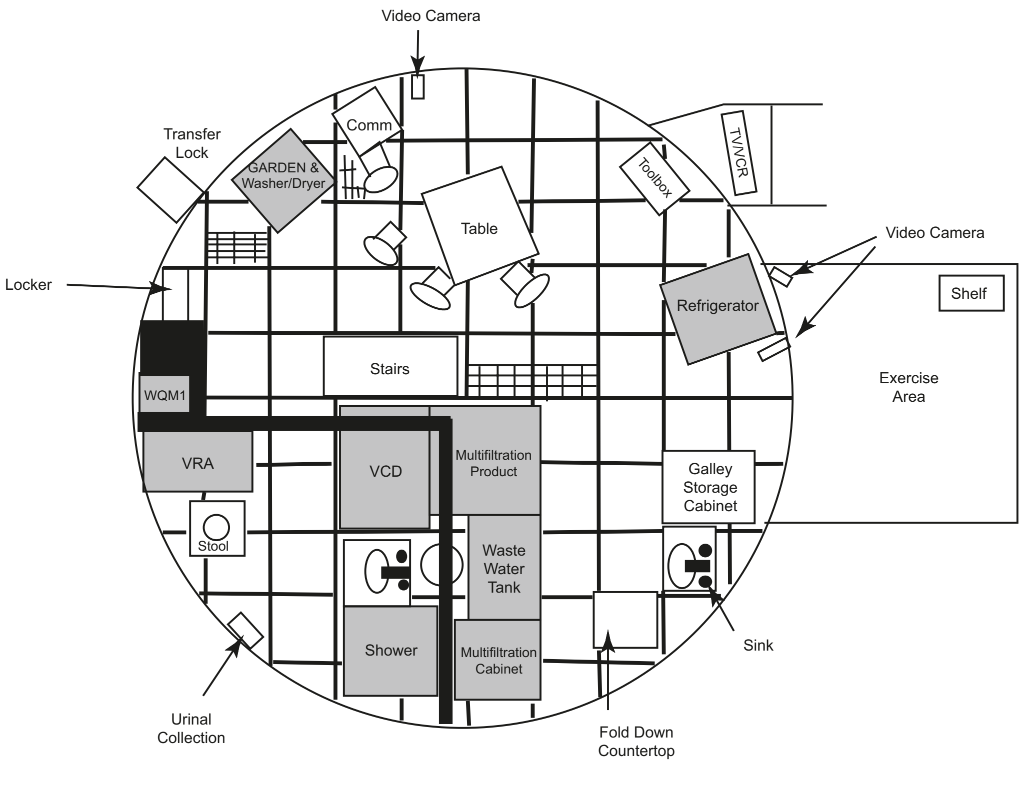

Figure 3.7-1 *Level One camera placement*

Level Two – Camera 3: Maintenance/Workstation

Level Two housed all principal equipment to support the basic functions of the chamber that were internal to it, including bioreactors and gauges. The average noise level in Level Two was 70 dB (3), and the lighting was provided by fluorescent fixtures arrayed vertically along the walls so that the occupants experienced a combination of glare and reflection at all locations on that level. A generous workstation table was provided on this floor, the same size as the wardroom table on Level One but without the crowding of the latter area.

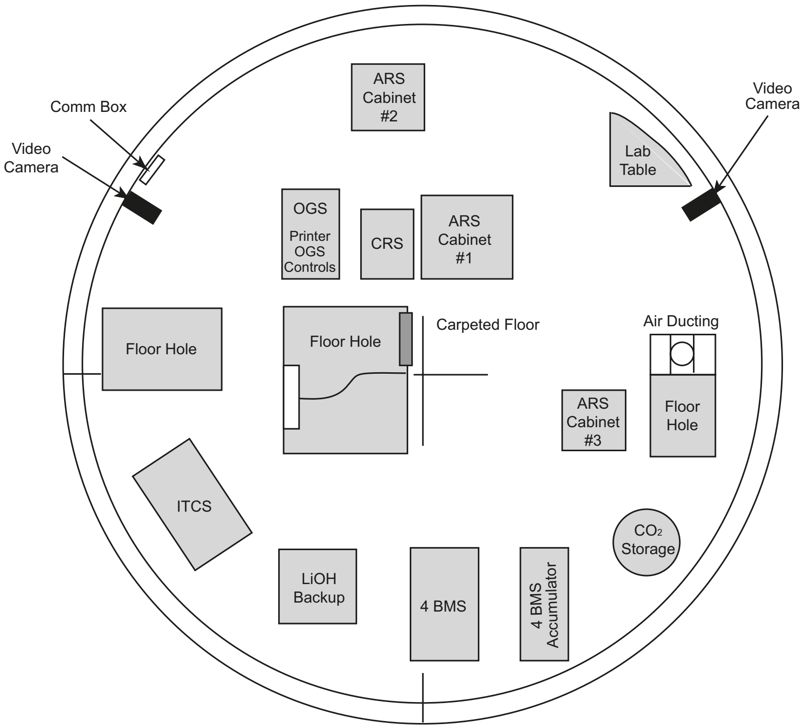

Figure 3.7-2 *Level Two camera placement*

Level Three – Camera 4: Crew Quarters

Level Three was the uppermost and most private level of the chamber, housing four identical crew quarters and a toilet all opening from a central landing at the head of the stairs.

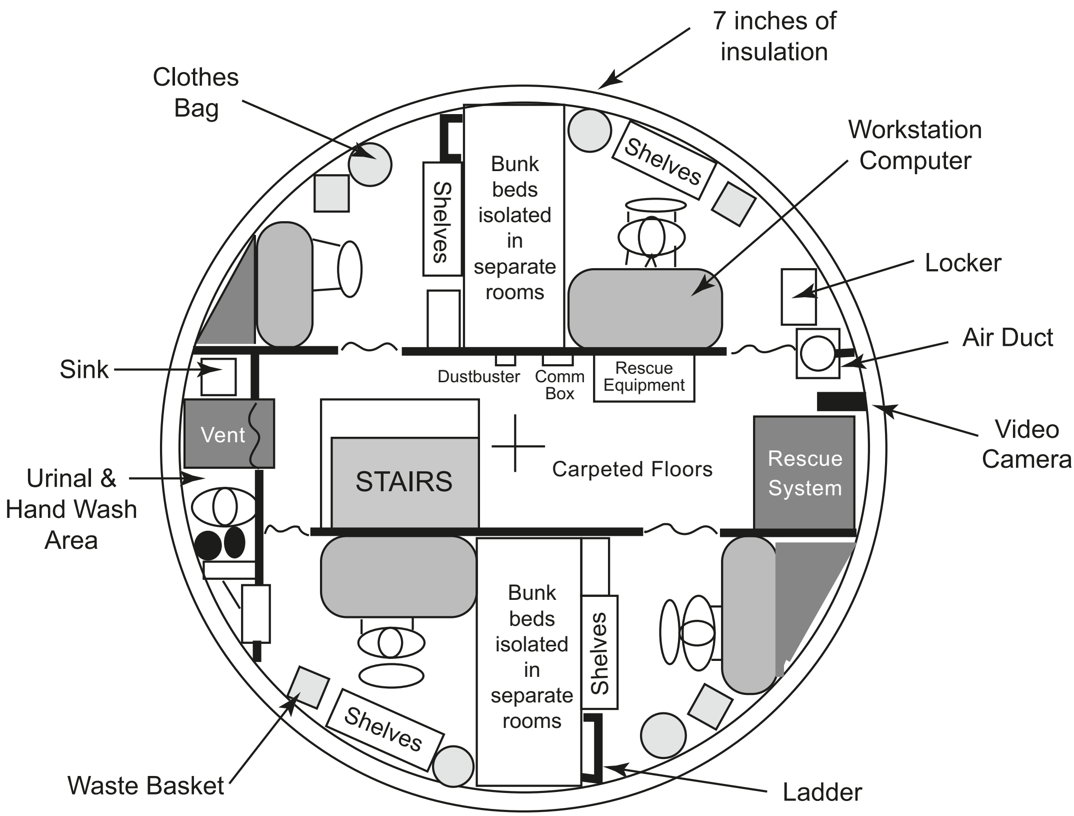

Figure 3.7-3 *Level Three camera placement*

Methods

In order to establish the habitable desirability of the various segments of the 20-foot chamber, it was essential first to find a quantitative, nonintrusive method of studying the patterns of use by which the four-person crew occupied the facility over three months. Because intrusiveness of any measurement system would inherently affect the data collected, the approach was winnowed down to one that used the four cameras, already present in the chamber, by which the Control Room maintained contact with the crew. The feed from these cameras was then recorded

24 hours a day, seven days a week, over three week-long spans of time. Since the question of adaptation or change was also a consideration, it was determined that data should be taken in the early, middle, and late stages of the test, specifically, weeks 3, 7, and 11.

Because the camera in Level Three records the public segment of that floor, off of which all four crew quarters are located, it was possible to note when the crewmembers were enjoying the privacy of their personal quarters without invading that privacy. Thus, the advantage was gained of having complete reasonable access to the crew's activities in a manner that was not intrusive. For instance, the Control Room protocol required that the crew be alerted to the fact that taping would commence at 00:00 that night on the evening prior to the onset of each week under scrutiny. Despite this alert, however, by week 3 – the first week studied – this was of negligible impact to the data because by this time the crew had become accustomed to the constant vigilance of the Control Room staff and had begun to ignore the presence of the cameras, or to accept them as a simple fact of daily life. An on-screen video time stamp was used which permitted the researchers to verify the time of the actual recording against the time marked on the cassette.

At the completion of the test, a total of 512 hours of video was then tracked using statistical analysis software known as SPSS 7.5, and the period of each crewmember's tenure on each floor was quantified in units of seconds. These units were then tracked against time, total duration, and the simultaneous activity of other crew.

The principal questions under consideration were:

- Did the crew's preference for group versus private areas or other use patterns change over the duration of their confinement?
- All things being equal (i.e., specific site-related activities aside), did the crew prefer more private locations or more public/shared locations?
- Were there any marked social patterns or behaviors that were anomalous to nonconfined groups?
- Were there any marked behaviors that reflect in an unambiguous fashion on known conditions of the crew's environment?

Findings

First, an analysis was made of the percentage of time the crew spent on each floor during each week of the test. Although there was less variation from week to week than had been anticipated, a slight but steady trend was seen toward less use of the airlock and Level One (the group areas) in favor of Level Three (private zones), as shown in Table 3.7-1.

Although this difference is not considered statistically significant, a significant trend was detected in the comparison of individual room usage within each week. Furthermore, this trend held true across all three weeks of testing. This trend was identified via post hoc Tukey's analysis as shown in Table 3.7-2.

Table 3.7-1 *Percentage of time spent on the floors*

	Week 3 (%)	Week 7 (%)	Week 11 (%)
3rd Floor	51.6	54.9	54.8
2nd Floor	4.0	2.7	3.0
1st Floor	41.4	40.0	39.9
Airlock	3.0	2.4	2.3

Table 3.7-2 *Post hoc: room usage differences within each week*

	3rd Floor	2nd Floor	1st Floor	Airlock
3rd Floor	—			
2nd Floor	S	—		
1st Floor	S	S	—	
Airlock	S	NS	S	—

S = Significant
NS = Not significant

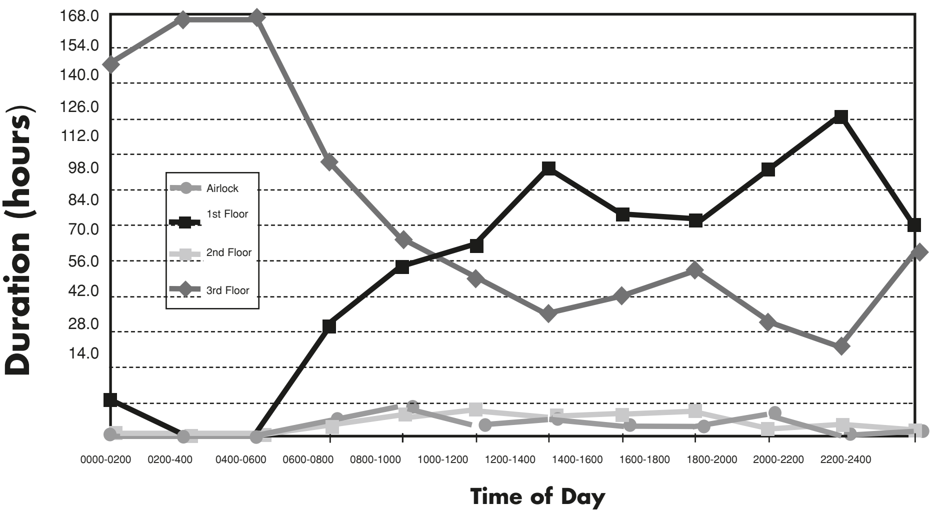

Figure 3.7-4 *Duration of floor use and time of day*

Of greatest interest for future refinements of this test is the analysis of the use patterns against time of day over the study period. Figure 3.7-4 (above) shows a temporal analysis which averages the usage over all three weeks. It is important to note that while the rates of use for the airlock and Level Two appear to be similar, the incidence of that use is utterly different. Because of the exercise function in the airlock, its use by only a single crewmember at a time was extended throughout the waking day with small peaks between 08:00 and 10:00 and between 18:00 and 20:00 as personnel used it for exercise. Level Two usage, however, was almost exclusively in 20-second increments steadily throughout the day – in other words, the amount of time it took for a person to traverse the Level Two landing on the stair while in transit between Levels One and Three. Occasionally, crewmembers would spend slightly larger blocks of time in Level Two in order to check or maintain equipment, but the greatest percentage of use stems from the transit function which was more or less constant throughout the day.

Another important (although less marked) data point was the set of locales for socialization. While Level One group interactions included any number of crewmembers up to four, the group interactions which took place on Level Three were noted to be interactions of never more than three and predominantly of only two persons at one time. Moreover, crewmembers were never seen entering one another's private quarters. The group appears from very early on to have established an unofficial protocol whereby people talking would stand just outside or in the doorway of another person's room, thus establishing a territorial boundary between the semi-private realm of the corridor/landing and the private realm of the crew quarters. Mutual-boundary interactions also took place as crewmembers stood in their own doorways and conversed with one another across the landing.

Use of Level One was almost perfectly mirrored by the use of Level Three; in other words, when personnel were not on one, the chances were very high that they were on the other (rather than in the airlock or Level Two). In many instances this use at specific times of day is unsurprising. Level Three, for example, was the area of choice between 24:00 and 08:00, while the crew was sleeping; and Level One was most popular around 12:00 and 20:00, at lunch and dinnertime.

However, this mirroring is also unaccompanied by anything but a static, constant baseline in the airlock and Level Two areas, suggesting that the use or disuse of Levels One and Three had bearing on one another but no bearing on the occupancy of Level Two and the airlock. Thus we note that two of the four areas of the habitat (some 35-40% of its total available area for habitable use) went virtually unused except by necessity, while the other two areas became in essence the whole inhabited volume of the test chamber.

IMPLICATIONS

By separate use of these terms we are establishing a distinction between "habitable" volume and "inhabited" volume. The difference between the former and the latter is that the former – "habitable" volume – **can** be occupied by humans, whereas the latter – "inhabited" volume – **will** be occupied and used by humans.

This is tremendously useful data because it tells us which environments the crew found acceptable, and which they did not. There is nearly overwhelming evidence here that the crew preferred Levels One and Three of the 20-foot chamber over the Airlock and Level Two. This is true to such a degree that these areas almost constitute wasted volume in that, despite the expressed needs of the crewmembers for greater privacy and flexibility within the habitat, they largely rejected the use of two semiprivate areas which could have been utilized as offline workstations and/or relaxation areas. In addition, the semiprivate landing area of Level Three could have become less of a public site for mutual-boundary interactions had it been possible for the crew to interact "offline" in some nonprivate room other than the Level One common area.

Thanks to this pattern of nonuse we are able to identify environmental factors which people clearly find unacceptable to the point of rejecting their use. The airlock is a small, cylindrical area that was not comfortably outfitted but rather housed only the exercise and other mechanical equipment. Furthermore, it was the only part of the habitat exposed to the exterior, so that something of a "goldfish bowl" sensibility may have held sway. Other than exercise, there was no other activity associated with the room and it had nothing to offer by way of welcome.

Level Two, on the other hand, had a pleasant level of illumination, carpeting, and a cozy corner or two to offer. Only two factors were less than optimal in its outfitting, yet these appear to have had a decisive effect on the usability of the room: the very loud acoustic environment, and the direct-glare lighting. While the room appeared calm, it was extremely difficult to make oneself heard for the noise generated by the equipment. Also, although the lighting levels were acceptable for tasks, the angle of lighting was extremely unpleasant.

Thus we have managed to derive a few important rules for design of inhabitable built environments:

1. Finishings, dimensions, and privacy affect the usability of the area,
2. High-glare illumination can render an area unusable to the resident population, and
3. An unacceptably loud acoustical environment can render an area unusable to the resident population.

The private/semiprivate/public boundary issues raised by interpersonal communications on Level Three also suggest some useful rules of programming (i.e., functional allocation of volume) for future hermetic habitats:

4. In a restricted habitat, private rooms are considered inviolable territory and will not be invaded unless by explicit invitation, and
5. The territory immediately adjacent to private rooms may/will be annexed as a semiprivate social center (unless other areas specifically intended for offline socializing are provided).

In any event, it is clear that environmental conditions do affect the efficiency and usability of the facility.

Forward Work/Conclusion

The next step from this point is naturally to repeat this test using specific factors as control and as test items in the habitat's environmental design. Because of this, the Hab element of JSC's BIO-Plex test facility was designed to allow investigators to use this method in testing specific questions concerning programming and volumetric allocation during future tests with human subjects. Specifically, the Hab is designed to accommodate the following tests for narrowing the field of questions:

1. Reconfigure the chamber between extended habitation tests in order to vary the balance of common, semiprivate, and private areas
2. Reconfigure the chamber between tests in order to vary the location of circulation and semiprivate areas and their relationship to common and/or private rooms
3. Reconfigure the chamber between tests in order to vary the relationship between common areas and workstations (i.e., galley, maintenance bench, office vs. wardroom/sitting room)
4. Control acoustic environment throughout the chamber
5. Configure and reconfigure lighting to test preferences for indirect, direct, and chromatically adjusted illumination, and
6. Change color and finishes to balance preference for "hot" vs. "cool" environments.

Sociokinesis – or, the movement patterns of a group – is a new but potentially highly valuable field of study in that it combines the fields of behavioral studies with environmental design. In its maiden run, this method already has established that there is a quantifiable relationship between environmental factors and human behavior. Taken to greater levels of detail and pursued in a diligent and scientific fashion, this study stands to offer a truly innovative set of data to guide designers in enhancing productivity and well-being through more usable environments. With proper follow-up this work will contribute significantly to the process of mitigating human-system risk for long-duration and exploration missions, as well as to the productivity and efficiency of many types of terrestrial structures and dwellings, such as submarines, Arctic stations, and other hermetic enclaves.

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